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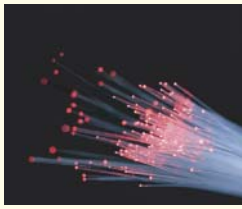

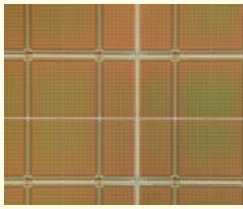



Foreword

This is the first issue of "Science and Technology Trends – Quarterly Review".

National Institute of Science and Technology Policy (NISTEP) established Science and Technology Foresight Center (STFC) in January 2001 to deepen analysis with inputting state-of-the-art science and technology trends. The mission of the center is to support national science and technology policy by providing policy makers with timely and comprehensive knowledge of important science and technology in Japan and in the world.

STFC has conducted regular surveys with support of around 3000 experts in the industrial, academic and public sectors who provide us with their information and opinions through STFC's expert network system. STFC has been publishing "Science and Technology Trends" (Japanese version) every month since April 2001. The first part of this monthly report introduces the latest topics in life science, ICT, environment, nanotechnology, materials science etc. that are collected through the expert network. The second part carries insight analysis by STFC researchers, which covers not only technological trends in specific areas but also other issues including government R&D budget and foreign countries' S&T policy. STFC also conducts foresight surveys such as periodical Delphi surveys.

This quarterly review is the English version of insight analysis derived from recent three issues of "Science and Technology Trends" written in Japanese, and will be published every three month in principle. You can also see them on the NISTEP website.

We hope this could be useful to you and appreciate your comments and advices.

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Executive Summary

Life Sciences

1 Trends in human genome analysis by the International Human Genome Sequencing Consortium and by Celera Genomics, and future prospects of post genome research in Japan

p.8

In February 2001, the International Human Genome Sequencing Consortium and Celera Genomics, a U.S. private company, separately published the rough draft of all bases that make up the human genome. Celera Genomics also announced that they are pursuing the identification of single nucleotide polymorphisms (SNPs) and proteins that are specifically expressed in cancer cells. In particular, identification of such proteins is being conducted with the aim to establish cancer diagnostic methods and to develop cancer vaccines.

In Japan, i) structural and variation analysis of human genome (human genome sequencing, identification of SNPs, etc.) as well as ii) functional analysis of human genome (structural and functional analysis of proteins, bioinformatics, etc.) have been promoted in order to take the opportunity of overcoming various diseases by utilizing the achievements in human genome sequencing.

This article describes trends in human genome sequencing and post genome research in Japan and abroad.

(Original Japanese version: published in May 2001)

2 Trends in Genetic Modified (GM) Plants and Foods

p.17

Genetic Modified(GM) plants and foods are indispensable for solving a variety of problems such as food crises and environmental concerns that are taking place worldwide. Moreover, thanks to the recent progression of researches on the plant genome, expectations are running high for the development of more useful GM plants. Under these circumstances, particular emphasis has been laid on R&D of GM plants in Japan.

On the other hand, there has been a lot of talk about the safety of GM plants from environmental and food perspectives over the past few years across the world. As a matter of fact, GM plants have yet to be fully supported by consumers in Japan – a situation that makes it difficult for the food industry and other industrial sectors to branch out into the development of GM plants and foods, and for universities and public research institutes to commercialize accomplishments of their basic researches.

This article addresses measures for promoting R&D and the safety of GM plants in response to the current circumstances surrounding GM plants in Japan.

(Original Japanese version: published in August 2001)

Information and Communication Technologies

3 Trends in Research and Development of Lithography Technology for Next-generation LSIs

p.29

One of the major contributors to the success of the Japanese semiconductor industry in maintaining the top share on the world market between the 1980s and the early 1990s was the superiority of the lithography technology, which is one of the key technologies. However, the Japanese semiconductor industry is losing superiority as its position of holding the top share in lithography steppers was taken by ASML of the Netherlands in 2000, and a EUV (extreme ultraviolet) lithography achieving the 0.03μm level was developed by the Consortium named EUV LLC, consists of the U.S. DOE (Department of Energy) Laboratories and semiconductor manufacturers in the US and Europe in April 2001.
This article explains the development strategies for lithography technologies in the U.S. and Europe, as well as trends in lithography technologies looking to the future.

(Original Japanese version: published in May 2001)

4 Raging Computer Viruses

p.33

From July through August 2001, two computer viruses—SirCam and CodeRed/CodeRed II—were running rampant throughout the world.
This article describes trends in recent computer viruses, with emphasis on these two viruses, and discusses why they became so widespread, while looking at the latest virus protection technologies.

(Original Japanese version: published in September 2001)

Environmental Sciences

5 Present status and problems associated with waste disposal technologies aiming at efficient utilization of energy contained in combustible wastes

p.37

One of the important goals in the environmental area is the realization of a recycle-oriented society, where recycling of resources is pursued, while effective resource utilization is promoted and generation of wastes is suppressed. For recycling of resources, while the Material Recycle will continue to be the basic option, the Thermal Recycle, in which non-recyclable wastes are recovered as energy through incineration, will also be necessary. For instance, waste incineration, currently practiced only for the purpose of reducing volume, needs to be reconsidered from an energy utilization point of view.
However, at present, waste incineration technologies that are to provide the basis of the Thermal Recycle are not yet fully established. For example, problems such as efficiency improvement of power generation and removal of dioxins, etc., are remained to be solved.
In this article, the present status of waste incineration technology, technological trends and problems requiring further breakthroughs are explained.

(Original Japanese version: published in June 2001)

6 A Trend of Hazardous Substance Detection in the Environment

p.43

Although physical and chemical measurement techniques such as gas chromatography/mass spectrograph (GC/MS) are employed today as the mainstream of environmental measurement, this does not necessarily mean that they are sufficient and satisfactory. Biological measurement techniques are drawing attention as a means to supplement the former, and various R&D efforts have been started.

In this article, techniques using individual organisms, organic substances and gene recombinant organisms are introduced. Furthermore, their positions in environmental measurement are considered and the future direction of development anticipated with environmental measurement is examined.

(Original Japanese version: published in September 2001)

Nanotechnology and Materials

7 New Superconducting Material MgB_2 and the Trends in Research and Development

p.48

Since the discovery of the superconductivity of MgB_2, many results of applied research for wires, thin films, and electronic devices, in addition to studies on superconductivity characteristics, have been announced in succession. This article reviews research and development trends in Japan and overseas relating to the metallic superconductor MgB_2 that has a high critical temperature beyond the past common thinking, and discusses the position of MgB_2 in the whole field of superconductivity research including the possibility that the clarification of the mechanism of superconductivity provides a guideline for the search of new superconducting materials.

(Original Japanese version: published in July 2001)

8 Trends in the Development of Carbon Nanotube Production Technology

p.54

The carbon nanotube (CNT) is a carbon nano-material that was found in Japan. Recently, application development has rapidly progressed in various fields making use of the unique characteristics of CNT.

Under such circumstances, development of the production technology that provides CNTs at a level of several kilograms per day is awaited.

In this article, recent trends in the development of CNT production technology and problems to be solved in the future are explained.

(Original Japanese version: published in July 2001)

Energy

9

The US's New National Energy Policy

—Supply-Focused Logic and Positioning of Each Energy Source—

p.59

On May 17, President Bush announced the "National Energy Policy (NEP)" revealing the framework of future energy policies.
Even though it contains a considerable amount of policy suggestions concerning the promotion of energy conservation and the utilization of renewable energies, the overall tone clearly sets forth a stance that attaches primary importance to expansion of energy supply capability.
This article surveys the logic focusing on the expansion of domestic energy supply capability, and the positioning of each energy source and related technologies in the NEP.

(Original Japanese version: published in June 2001)

1

Trends in Human Genome Analysis by the International Human Genome Sequencing Consortium and by Celera Genomics, and Future Prospects of Post Genome Research in Japan

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1.1 Introduction

Human genome is the genetic blueprint of the human being, which conveys all genetics information necessary for a human. In general, the term "human genome" refers to the DNAs on 22 pairs of autosomal chromosomes and 2 sex chromosomes. DNAs contain 4 kinds of bases (adenine, guanine, cytosine and thymine), and human genome is composed of about 3 billion base pairs. It has been said that, among all the base pairs making up the human genome, only about 3% corresponds to genes (regions encoding genetic information).

The concept of the sequencing of the whole human genome was already created in the mid 1980s. However, for reasons such as the fact that an extremely long time was required to sequence the whole human genome with the use of techniques for sequencing at that time, sequencing of the whole human genome was thought to have only limited feasibility. However, research on human genome has gradually become active, and, in 1990, the International Human Genome Sequencing Project was launched on a full scale under the initiative of the United States. While the project was originally planned to be completed in 15 years, the date for the project's completion has been brought forward because of the increase in performance of genome sequencers as well as the entry of venture capital companies into the project. As a result, in February 2001, the Human Genome Sequencing Consortium and Celera Genomics, a venture capital company in the United States, separately published that they have almost finished the sequencing of the whole human genome.

The research conducted by utilizing the determined base sequence of human genome is called "post genome research." Since post genome research includes many factors that may lead directly to future commercial applications, cutthroat world-wide competition involving private companies has been carried out in this field.

This article summarizes the international trends in human genome sequencing, trends in research performed by Celera Genomics, a noteworthy venture capital company in the United States, as well as trends in post genome research in Japan.

1.2 International trends in human genome sequencing

In February 2001, the International Human Genome Sequencing Consortium and Celera Genomics separately published articles on human genome sequencing in the journals "Nature" and "Science," respectively (Chart 1).

1.2.1 Sequencing by the International Human Genome Sequencing Consortium

Chart 2 shows the number of bases in finished human sequences among the human genome sequences entered into GenBank, a public base sequence database.

With regard to the complete sequencing of a specific pair of chromosome, a joint research team composed of researchers from Japan, the United Kingdom and the United States (Keio University, Sanger Centre in the United Kingdom, as well as the University of Oklahoma and Washington University in the United States) finished the

complete sequencing of chromosome 22. In addition, Keio University, the Institute of Physical and Chemical Research, etc., collaboratively finished the complete sequencing of chromosome 21 in May 2000. The accuracy of the sequencing of those chromosomes (chromosomes 21 and 22) is as high as 99.99%, earning an excellent reputation worldwide. Chromosome 22 has the gene responsible for Parkinson's disease, genes related to autoimmune diseases, etc., and chromosome 21 has relations with Down's syndrome (an extra chromosome 21 is detected in Down's syndrome), a gene related to Alzheimer's disease, etc. The sequencing of human genome including such disease-related genes as those mentioned above is expected to greatly expedite the progress in research on the mechanism of expression of those genes.

However, there still remain draft sequences, i.e., regions that are difficult to be completely sequenced on chromosomes other than chromosomes 21 and 22. The International Human Genome Sequencing Consortium is still pursuing the sequencing project, aiming to complete the sequencing of the whole human genome with high accuracy by the end of 2003.

1.2.2 Human Genome Sequencing by Celera Genomics

Celera Genomics did not sequence each chromosome separately but adopted the whole genome shot-gun method where all the 24 chromosomes (22 pairs of autosomal chromosomes and 2 sex chromosomes) were

Chart 1: Publishers of the human genome sequence

Journal Title	Nature February 15, 2001 issue "Initial sequencing and analysis of the human genome"	Science February 16, 2001 issue "The Sequence of the Human Genome"
Publisher	International Human Genome Sequencing Consortium ● United States (Washington University; Joint Genome Institute, Department of Energy; Baylor College of Medicine; Whitehead Institute, Massachusetts Institute of Technology, etc.) ● United Kingdom (Sanger Centre, etc.) ● France (Genoscope, etc.) ● Japan (Institute of Physical and Chemical Research [Riken], Keio University, etc.) ● Germany, etc.	Celera Genomics (American venture capital company)

Chart 2: Finished human sequences entered into GenBank by institutions participating in the International Human Genome Sequencing Consortium

Order of entry	Research Organization	Number of bases sequenced (kb)
1	The Sanger Centre (United Kingdom)	284,353
2	Washington University Genome Sequencing Center (United States)	175,279
3	US DOE Joint Genome Institute (United States)	78,486
4	Baylor College of Medicine Human Genome Sequencing Center (United States)	53,418
5	Genoscope (France)	48,808
6	Whitehead Institute, Center for Genome Research (United States)	46,560
7	Department of Genome Analysis, Institute of Molecular Biotechnology (Germany)	17,788
8	Institute of Physical and Chemical Research (Japan)	16,971
9	University of Washington Genome Center (United States)	14,692
10	Keio University (Japan)	13,058
	Others	92,614
	Total	842,027
	(Total number of bases on the whole human genome.)	about 3,200,000

Prepared by the Science and Technology Foresight Center based on Table 3 on page 868 in the February 15, 2001 issue of the journal Nature.

simultaneously analyzed. At the first step of Celera's whole genome shot-gun protocol, sampled human genome was randomly physically sheared into small fragments of the same size (2 kb or 10 kb) by using ultrasound, and a library of the fragments was constructed. At the next step, the regions composed of about several hundred base pairs at both ends of those fragments were analyzed in DNA sequencers. Scientists then used powerful computers to assemble the fragments back into place to determine the sequence of the whole human genome. According to Celera Genomics, with the whole genome shot-gun method, 95% of the whole human genome could be sequenced with an accuracy of as high as 99.96%.

1.2.3 Access to the data on base sequences of human genome

While the data on human genome sequences entered into GenBank by the International Human Genome Sequencing Consortium can be accessed at no charge, you need to make a contract with Celera Genomics in order to gain access to the data on human genome sequences determined by the company.

(1) Human genome sequences determined by the International Human Genome Sequencing Consortium

In the sequencing activities by the International Human Genome Sequencing Consortium, respective participating institutions are assigned specific regions to be sequenced, and, if the sequencing of a region is finished, the data on the sequence of the region are to be immediately entered into public databases including GenBank and then made available for public view at no charge. Those data entered on such public databases include data on the base sequences of the finished human sequences such as those of chromosomes 21 and 22 as well as data on the regions on draft sequences. As mentioned in section 1.2.1, the sequencing of the whole human genome must be completed by the International Human Genome Sequencing Consortium before free access and utilization of data on the sequence of the whole genome with high accuracy become possible.

(2) Human genome sequences determined by Celera Genomics

Researchers, institutions, companies, etc., cannot freely access or utilize the data on human genome sequences obtained by Celera Genomics unless they make a contract with the company. In Australia, for example, a contract with Celera Genomics has been made at a nation level, and national institutions have access to the data on human genome sequences determined by the company. In Japan, some universities and private companies individually contracted with Celera Genomics to access the data on sequences determined by the company.

1.3 Accomplishments in genome sequence analysis achieved by Celera Genomics and strategies for pursuing post genome research

In March 2001, Dr. J. Craig Venter, president of Celera Genomics at the time, visited Japan, and he commented as follows at his lecture, etc., about genome sequence analysis and strategies for pursuing post genome research:

(1) Accomplishments in genome sequence analysis

Celera Genomics, which was founded in 1998, has determined the sequences of genomes of the Drosophila (fruit fly), human beings, and mice (3 strains of mice including 129SvJ, DBA/2 and A/J). Currently, the company is pursuing the sequence analysis of canine and rat genomes. The company has been able to accomplish a succession of achievements in a short period of time against the backdrop of; i) the introduction of 300 units of a new automated sequencer (ABI3700), ii) development of software for the whole genome shotgun sequencing technique, and iii) the introduction of the latest computers. In other words, Celera Genomics has succeeded in climbing on the bandwagon in terms of both hardware and software.

(2) Current state of human genome sequence analysis

The evolutionary process can be traced in human genome. When viewing the sequences of the human genome, many regions with similar sequences can be seen on different chromosomes, indicating that they have evolved from a common ancestral chromosome.

In addition, while individual difference is noted in the sequences of some regions on the human genome, roughly 3 million single nucleotide polymorphisms (SNPs) have been found which are DNA sequence variations that occur when a single nucleotide (A, T, C or G) in the genome sequence is altered. Ultimately, 4 million SNPs will be found. Among them, 1% or less exists on coding regions of the human genome (genes), and only a fraction of those SNPs cause amino acid substitution. On the other hand, it is known that SNPs that occur in non-coding regions could predispose people to disease or influence their response to a drug, so such SNPs (SNPs in the regions not encoding proteins) are also of consequence.

(3) Strategies for pursuing post genome research

At the facility for protein analysis (Proteomics Factory), which has been established by Celera Genomics, one million samples of proteins can be structurally analyzed in a day with the use of mass spectrometers. Celera Genomics thinks that about 250 thousand kinds of proteins are expressed from roughly 30 thousand human genes by way of genetic transcription, translation and post-translational processing, and expects that causal relationships can be found between abnormalities of proteins and diseases. They have targeted cancer and aim to develop cancer diagnostic methods and cancer-specific vaccines.

According to the media, Celera Genomics has made a capital investment in a Japanese venture capital biotechnology company, which has SNPs analysis technology and aims to reveal, for example, the association between SNPs in Japanese and diseases.

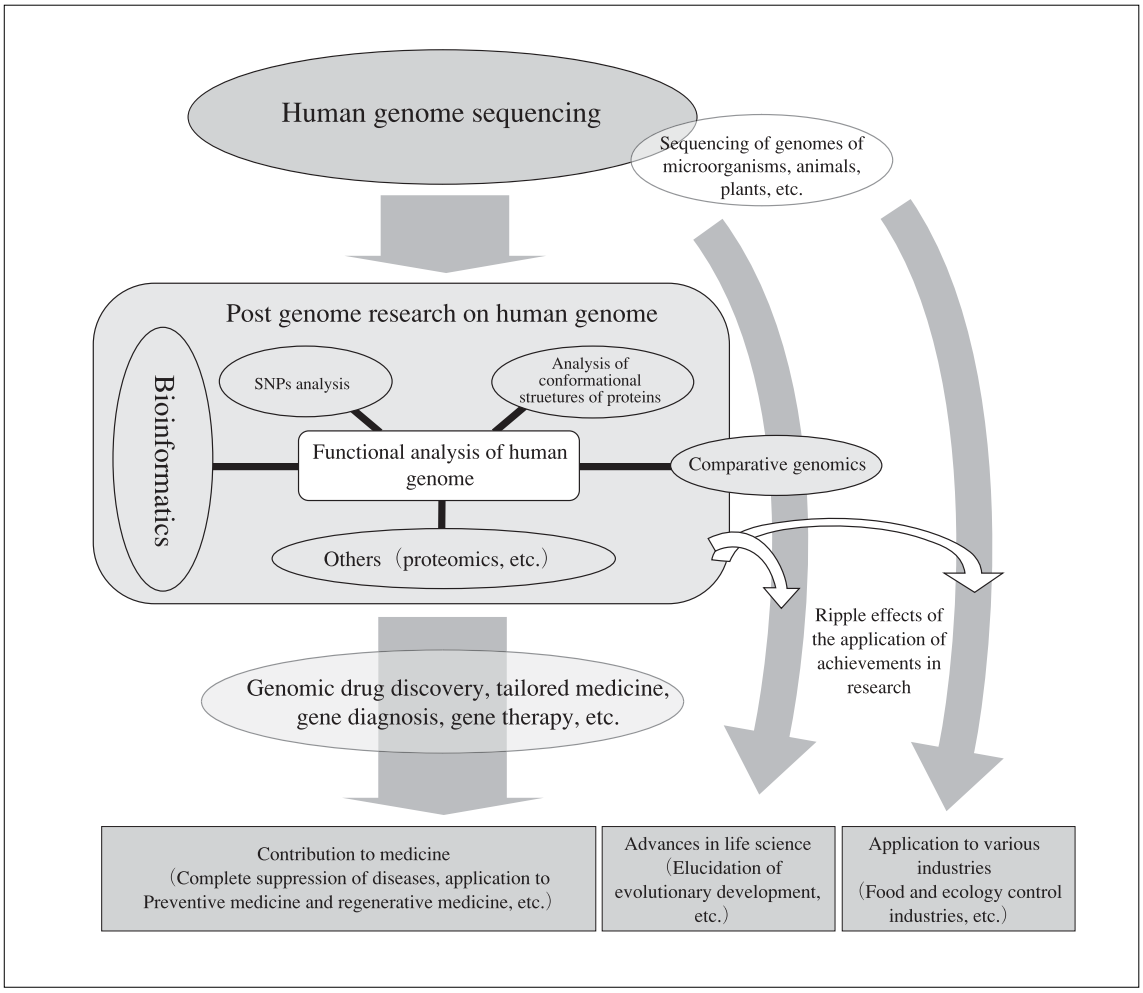
1.4 Trends in post genome research in Japan

Post genome research on human genome may have ripple effects on various fields in the form of, for example, contributions to medical care, facilitation of progress in advances in life science, contributions to various industries, etc. shown in Chart 3.

Such post genome research has come to be accepted as important in the Phase Two Technology Master Plan, which was adopted at the Cabinet meeting held in March 2001. The plan states that, among the areas of life science given priority to in research and development in Japan, post genome research should be given high priority and pursued strategically among others.

Future directions of post genome research in Japan are concretely charted in the report entitled "Promotion of strategies for pursuing post genome research" (report on a round-table conference concerning the strategic promotion of post genome research held by the Policy-making committee of the Technology Council) published in December 2000. The report states that the areas of post genome research that must be urgently pursued in Japan include the analysis of human genome variability and genes related to diseases, structural and functional analysis of proteins, bioinformatics, as well as functional analysis of genome. In addition, the report said that Japan will be able to move ahead of other countries in post genome research through urgent pursuit of such research by utilizing technologies in Japan that are superior to those in other countries such as the techniques for creating full-length cDNAs containing the complete genetic information of the mRNA encoding amino acids, which are used to form proteins (technique developed by Dr. Sugano et al. at the Institute of Medical Science, the University of Tokyo, and that developed by Dr. Hayashizaki et al. at the Institute of Physical and Chemical Research), and techniques for inducing the expression of proteins in the cell-free system (technique developed by Dr. Yokoyama et al. at the Institute of Physical and Chemical Research for efficiently inducing the expression of, and preparing the sample of many

Chart 3: Post genome research on human genome



Prepared by the Science and Technology Foresight Center

kinds of proteins), as well as by utilizing "facilities" in Japan that are better equipped than those in other countries including the large-scale nuclear magnetic resonance (NMR) park (Genomic Science Center, Institute of Physical and Chemical Research) and "SPring-8," a third-generation synchrotron radiation facility, at the Japan Synchrotron Radiation Research Institute (JASRI).

In the budget plan for fiscal year 2001, 98.3 billion yen was earmarked for the "strategies of promoting research and development in the areas of biotechnology with an eye toward life science of the 21st century" by the Ministry of Education, Culture, Sports, Science and Technology, the Ministry of Agriculture, Forestry and Fisheries, and the Ministry of Health, Labor and Welfare. Of the 98.3 billion yen, 60.6 billion yen (compared to 44.4 billion yen in fiscal year 2000) was allocated to; i) analysis of human genome structure and variability (structural and functional analysis of human full-length cDNAs, research on SNPs, etc.) and, ii) functional analysis of the human genome (structural and functional analysis of proteins, bioinformatics, etc.) to further facilitate such research.

Concerning post genome research pursued in Japan, this article describes trends in analysis of conformational structures of proteins, studies on SNPs found in Japanese as well as bioinformatics.

(1) Analysis of conformational structures of proteins

No methods, which are based on the sequences of the genome and are universally applicable, have been found for predicting the functions of proteins that are to be expressed from genes via transcription and translation. However, projects for analyzing conformational structures of proteins, which may be closely associated with their functions, are underway at institutions including the Institute of Physical and Chemical Research.

So far, conformational structures of 2,000 to 3,000 kinds of proteins have been elucidated, most of which have been clarified in the United States.

The international research team composed of researchers from Japan, the United States and European countries is planning to elucidate the conformational structures of 10,000 or more kinds of proteins within the next 5-10 years. Japan is aiming to complete the analysis of conformational structures of about 3,000 kinds of proteins under the initiative of the Institute of Physical and Chemical Research within the next five years. Moreover, the United States is targeting for the completion of conformational analysis of roughly 5,000 kinds of proteins within the next 5 years. While only a few percent of the whole sequences determined by the International Human Genome Sequencing Consortium was elucidated by Japanese researchers, it can be expected that a larger percentage will be represented by conformational structures of proteins determined in Japan among whole structures identified in the world.

In the First International Structural Genomics Meeting jointly held under the auspices of Japan, the United States and the United Kingdom in April 2001, discussion was held by the representatives of 10 countries on the conceptual framework of international cooperation in protein analysis. In the conference, it was agreed that situation reports on research should be made through common procedural steps based on the rule that every piece of information obtained in such analysis must be made public. Moreover, with regard to the timing of the publication of data on the conformational structures of proteins, it was agreed that such data must be made public within 6 months at the maximum after obtaining the relevant data, by giving consideration to the possible unfairness that may be caused due to the difference in patent application systems among countries and in view of the fact that such data may directly lead to future commercial applications such as the development of diagnostic methods and pharmaceutical products.

(2) Study on SNPs found in Japanese

Individual differences are seen in the sequences of many regions of the human genome. Such differences in base sequences are called genetic polymorphisms which include; i) SNPs, ii) insertion or deletion polymorphisms (polymorphisms due to the insertion or deletion in some regions of DNA), as well as iii) VNTR (variable number of tandem repeat) polymorphisms and microsatellite polymorphisms (polymorphisms caused by the difference in the number of repeat of a specific sequence made up of two to several tens of bases; those due to the differences of repeat number of sequences made up of a few to several tens of bases and 2-4 bases are called VNTR polymorphisms and microsatellite polymorphisms, respectively).

While VNTR and microsatellite polymorphisms can be found in several thousands and several tens of thousand regions on the genome, respectively, it has been said that SNPs are found in about as much as 4 million regions (according to Dr. J. Craig Venter, former president of Celera Genomics) or in as much as 3-10 million regions (Prof. Yusuke Nakamura, "Frontiers of Genetic Medicine," Yodosha Co., Ltd., 2000). In addition, since high-speed and high throughput SNPs analyzers are nearing practical use, SNPs may be more useful in exploring disease-related genes. Therefore, researchers assign a higher importance to SNPs as compared with other polymorphisms.

Under these circumstances, analysis of some of the SNPs found in Japanese was conducted at the Institute of Medical Science, University of Tokyo, and yielded results that suggest Japanese have descended from a relatively genetically isolated population, indicating the possibility that there might be disease-related SNPs specific to Japanese. The Institute of Medical Science, University of Tokyo, has compiled data on SNPs into a computer database and put it up for public view on the Internet. In addition, the Pharma SNP Consortium (organized by the Institute of Physical and Chemical Research, Tokyo Women's Medical University, as well as 43 pharmaceutical companies) is pursuing studies that may lead to the promotion of tailored medicine including the collection of DNA samples from a general population (about 1,000 healthy volunteers) for use in the analysis of polymorphisms of the 165 genes related to drug metabolizing enzymes.

It is expected that data on regions on the human

genome in which individual differences are seen in base sequences will be the key to future individualized medical care, i.e., medical care designed for each individual to offer maximum therapeutic benefits in light of accurately analyzing his/her genetic predisposition. On the other hand, ethical problems have loomed about how to handle individual genetic information. In March 2001, the Ministry of Education, Culture, Sports, Science and Technology, the Ministry of Health, Labor and Welfare, and the Ministry of Economy, Trade and Industry jointly drew up the "Ethical Guidelines concerning the Analysis of Human Genome and Genes," which are the concrete guidelines for ethical aspects of research on human genome and genes in general. In the guidelines, responsibilities to be assumed by researchers and institutions included the pursuit of genetic studies after gaining written informed consent from the candidate suppliers of DNA samples following detailed explanation of, for example, the purposes of the relevant studies as well as the guaranteed protection of privacy in terms of genetic information. Moreover, 8 genetic medicine-related societies in Japan including the Japan Society of Human Genetics have jointly drawn up draft guidelines as to the way human genetic tests should be carried on.

(3) Bioinformatics

Rapid progress in human genome analysis has created a need for processing enormous amounts of data on base sequences. In order to accelerate the progress in post genome research from now, it may be essential to develop software that enables us to not only manipulate data on base sequences but also to predict the structures, functions, metabolic pathways, etc., of proteins based on amino acid sequences. Therefore, further facilitation of studies in the field of bioinformatics, in which databases of information that may form the foundation of post genome research are constructed to associate the extensive data to one another, is thought to be an urgent necessity. In particular, development of human resources, such as specialists who are experts in both biology and information science, has long been considered to be a matter of high priority.

One example of specific efforts made by the Japanese government is that bioinformatics was selected as one of the fields (two fields in total were selected) from among the research fields proposed by the general public as those for which monetary support for the development of human resources must be provided from the Funds for the Coordination of Advancement of Technology for fiscal year 2001.

In addition, one example of a recent noteworthy movement is that a seminar, "Information Biology Teki-juku (training course for people with Aptitude)" (Director: Dr. Kenichi Matsubara, professor at Nara Institute of Science and Technology), was held during the period from late March to early April 2001 at the International Institute for Advanced Studies, under the sponsorship of the Ministry of Education, Culture, Sports, Science and Technology, with the aim of training professionals on information technology necessary for studies in the field of life science who can then be trailblazers and explore new areas. These realities suggest that researchers also recognize the significance of bioinformatics.

In the United States, biology is compulsory for all students regardless of their specialties at some universities, which would give a clue in devising strategies for promoting the progress in bioinformatics.

1.5 Conclusion —Future prospects of the movement surrounding human genome sequences

(1) Human genome sequencing by the International Human Genome Sequencing Consortium is currently in progress

Currently, human genome sequencing is being pursued by the Finishing Group (composed of researchers from the United States, the United Kingdom, Japan and France) of the International Human Genome Sequencing Consortium, with the aim to complete the sequencing of the whole human genome with high accuracy. In the Finishing Group, there are coordinating centers that are responsible for the sequencing of specific chromosomes as well as participating centers that are to cooperate with sequencing chromosomes where possible.

In Japan, the Institute of Physical and Chemical Research, a coordinating center, is pursuing the sequencing of chromosomes 11 and 18 in collaboration with the Whitehead Institute, Massachusetts Institute of Technology. On the other hand, Keio University, a participating center, is engaged in the sequencing of chromosome 8.

(2) Applicability of genome research to disease suppression

In order to apply the achievements in genome research to disease suppression, it is necessary to analyze such data on genome sequences as those on SNPs in association with data on clinical characteristics. The association method is one example of such analytical methods with which candidate disease-related genes will be identified through comparing gene sequences of each population of several hundred to several thousand people affected by a specific disease with those of each population of several hundred to several thousand people free of the disease. For such analysis, blood samples must be collected from a relatively great many volunteers.

Japan lags behind some other countries in the establishment of foundations on which to conduct studies using such analytical method mentioned above. It is difficult to collect blood samples from a great many people at the level of each individual institution and, therefore, some researchers obtain such blood samples from abroad.

From here forward, in order to build up a solid foundation on which to do post genome research in Japan, it is urgently required to establish resource centers where samples and clinical data collected from many people, while following specified procedures such as gaining informed consent, are stored and managed at a national level.

(3) Promotion of post genome research

In recent post genome research, the United States has taken the international initiative, against the backdrop of the aggressive establishment of venture capital biotechnology companies, to develop strategies for obtaining and protecting U.S. patents. For example, about 1,500 venture capital biotechnology companies were reported to be established in the United States in 2000, in contrast to about 150 companies in Japan (Masamichi Ooishi, "Workings of Human Genome," Nippon Jitsugyo Publishing Co., Ltd., 2001).

Nevertheless, in Japan too, such various projects as those mentioned under Section 1.4 of this article have been prepared or launched under the initiative of government. Private companies including pharmaceutical companies are also hurriedly promoting larger investments in research targeting at genomic drug discovery, and forming alliances for the sake of improving their competitiveness in the field of bioinformatics as well as promoting technical cooperation. Furthermore, joint research projects between such public institutions as the Institute of Physical and Chemical Research and private companies have been pursued, raising expectations that the achievements in publicly funded studies will lead to future commercial applications.

Post genome research will have an enormous impact on Japan's future life and economy, and will be deeply involved in various aspects of society, primarily concerning the ethical aspects. Therefore, it may be required that research funds and manpower be provided, while flexibly responding to changes in the social climate surrounding post genome research as well as in the environment for such research in Japan and abroad, for its acceleration.

Commentary

Percentage of base sequences determined by Japanese among whole sequences analyzed by the International Human Genome Sequencing Consortium

It has been frequently reported by the media, etc., that the rate of Japan's contribution to human genome sequencing pursued by the International Human Genome Sequencing Consortium is about 6%. This value was calculated based on the percentage (5.59%) of the total of sequences (3,934,884 kb) determined by the Institute of Physical and Chemical Research (188,056 kb), Keio University (20,105 kb), and Tokai University together with two societies for the study of cancer (11,783 kb in total) in the whole draft sequences determined by the Consortium.

As of February 2001, when the article contributed by the International Human Genome Sequencing Consortium appeared in the journal Nature, as much as 4,338,224 kb were contained in the whole draft sequences, far exceeding (about 1.4 times) the estimated number of bases making up the human genome. Such increase in bases in draft sequences is due in part to the fact that institutions in countries other than Japan entered the data on the sequences of the regions not assigned to them, which they determined in order to explore SNPs entered into databases.

The values in Chart 2 are not the numbers of bases in the draft sequences, but those in finished human sequences.

2

Trends in Genetic Modified(GM) Plants and Foods

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2.1 Introduction

Genetic Modified (GM) plants and foods are expected to contribute to solving various problems such as food crises and environmental concerns. In particular, GM plants with useful properties are on the verge of commercialization thanks to the recent dramatic developments in genome studies. Under these circumstances, expectations are running high across the world for the development of GM plants.

On the other hand, the majority of Japanese people are not necessarily longing for the early commercialization of GM plants and foods. Underlying this situation is a stable supply of food supported by domestic production and imports, as well as lingering concerns among consumers about the safety of GM foods.

Over the medium and long term, however, the following can be justified:

- The government is responsible for assuring its citizens of a stable supply of food under the adverse circumstances where demand for food is increasing worldwide in response to the expanding population, and food production is expected to decline due to global warming and other factors.
- While Japan is increasingly becoming a nation of old people, technological innovation in food is expected to play a major role in increasing healthy life expectancy, and creating a vital aging society.

It is thus very important to push forward with Research and Development(R&D) of GM plants and foods as a national policy.

In order to carry out a series of basic plans for science and technology, a general meeting for science and technology recently mapped out "The 2002 Guidelines for the Distribution of Budget and Resources to Science and Technology." of priority areas in life sciences, the guidelines place particular emphasis on R&D of GM plants and foods as follows:

- Preventive and therapeutic technology that contributes to creating a vital aging society: improve preventive measures through development of functional foods.
- Technology necessary for food, the environment, and production of goods: promote genome analysis of plants and microorganisms, and make use of the accomplishments of the analysis in order to improve the production process of useful substances, and to develop various quality crops, environmental-stress-resistant crops, and biodegradable technology for environmental pollutants.

This article addresses measures for promoting R&D and the safety of GM plants in response to the current circumstances surrounding GM plants in Japan.

2.2 The Present Situation of GM Plants

2.2.1 GM Plants Developed in the World

Chart 1 shows GM plants up to now developed in the world.

In 2000, the total growing area of GM plants stood at 40 million ha, 50% of which was for herbicide-resistant soybean, and 30% for insect-resistant corn. As of 2000, 13 countries have tried commercial plantation of GM plants, and the growing area is expanding with the U.S. commanding about a 70% share.

2.2.2 Plantation of GM plants and GM Foods in Japan

Chart 2 shows the GM plants, plantation of which is approved, and the safety of which as food has been verified in Japan.

However, small-scale plantation of carnation has been the only commercial production of GM plants in Japan. The Plant Protection Law bans imports of fresh potato and sugar beet, while they can be imported in the form of processed food.

2.2.3 Classification of GM Plants by Objective

GM plants can be classified into several groups by objective, as shown in Chart 3.

In general, GM plants have been developed primarily for ensuring stable yields of crops by reducing damages caused by herbicides and insects – e.g., insect-resistant plants incorporated with the genes of insect-control protein isolated

Chart 1: GM Plants Developed in the World

Designed Properties	Crops
Herbicide-Resistant	Soybean, Cole, Corn, Cotton, Rice, Wheat, Sugar beet, Potato, Tomato, Flax, Poplar
Insect-Resistant	Corn, Cotton, Soybean, Potato, Cole, Rice, Tomato, Eggplant, Apple, Tobacco, Sugar Cane
Herbicide- Insect -Resistant	Corn, Cotton
Disease-Resistant	Papaya, Squash, Rice, Wheat, Carrot, Eggplant, Tomato, Potato, Cucumber, Watermelon, Onion, Strawberry, Melon, Sweet Potato, Sugar Cane, Sunflower, Tobacco, Grape, Apple, Cole, Soybean
Improved Productivity	Corn, Rice, Wheat, Cole, Soybean, Tomato
Poor-Environment-Resistant	Tomato, Carnation, Wheat, Cotton
Long shelf Life	Tomato, Carnation, Strawberry, Melon, Petunia
Improved Ingredients or Functions	Oleic-Acid-Rich Soybean, Lauric-Acid-Rich Cole, Vitamin-Rich Rice (containing beta carotene), Rice Containing Engineered Protein, Soybean Containing Engineered Protein, Amino-Acid-Rich Wheat (methionine), Potato Containing Engineered Starch (low in amylose), Cotton Containing Engineered Fiber, New Color Carnation

Source: The Agriculture, Forestry and Fisheries Research Council

Chart 2: Plantation of GM plants and GM Foods in Japan (as of July 23, 2001)

Plants	Added Properties	
	Those Proved to be Safe for Plantation in Fields	Those Proved to be Safe as Food
Adzuki bean	Insect-Resistant	
Rice	Virus-Resistant, Low Allergen, Low Protein (suited for sake brewing), Low Glutelin, Herbicide-Resistant	
Carnation	Long shelf Life, Different Colors	
Cauliflower	Herbicide-Resistant, Male Sterility	
Cucumber	Gray-Mold-Resistant	
Potato		Insect-Resistant
Soybean	Herbicide Resistant	Herbicide-Resistant, Oleic-Acid-Rich
Sugar beet		Herbicide-Resistant
Maize (Corn)	Herbicide Resistant, Insect-Resistant	Herbicide Resistant, Insect-Resistant
Tomato	Virus-Resistant, Pectin-Rich, Long shelf Life	
Torenia	Different Colors	
Cole (Rapeseed)	Herbicide-Resistant	Herbicide-Resistant, Male Sterility, Improved Fertility
Broccoli	Herbicide-Resistant, Male Sterility	
Petunia	Virus-Resistant	
Melon	Virus-Resistant	
Cotton		Insect-Resistant, Herbicide-Resistant

Source: Home Page of the Ministry of Agriculture, Forestry and Fisheries of Japan ; Prepared by the Science and Technology Foresight Center

from Bacillus thuringiensis (Bt); plants that are resistant to herbicides such as glyphosate agents; and plants that are resistant to diseases caused by viruses. These GM plants, which are referred to as "the first-generation GM plants," benefit producers by saving labor on such things as crop-dusting.

In the meantime, development of the second-generation GM plants, elements or taste of which are modified, is on the rise. These are high value-added plants in terms of food, and hence they bring great benefits to consumers – e.g., oleic-acid-rich soybean having the properties of reducing blood-cholesterol levels, and low-allergen rice that inhibits production of allergens.

Some of the next-generation GM plants are intended for contributing to developing countries where good health is hard to come by and the distribution of pharmaceuticals is virtually non-existent. Specifically, some GM plants are designed to function as pharmaceuticals – e.g., plants with properties of oral vaccines, and plants rich in beta-carotene, a base element of vitamin A, which prevents visual impairment.

Other plants having the same properties as those

Chart 3: Classification of GM Plants by Objective

Crops	Added Properties
(1) Plants that Benefit Producers	Herbicide-Resistant Plants, Insect-Resistant Plants, Virus-Resistant Plants, High-Yielding Plants, Salt-Resistant Plants, Drought-Resistant Plants, etc.
(2) Plants that Benefit Consumers	High-Quality Plants (Oleic-Acid-Rich Plants, etc.), Tasty Plants, Low-Priced Plants, etc.
(3) Plants for Maintaining Health and Treating Diseases in Developing Countries	Vitamin-A-Rich Plants, Plants Producing Live Vaccines, Plants Producing Diagnostics, etc.
(4) Plants for Rehabilitating the Environment	Plants Absorbing or Decomposing Heavy Metals, NOx and SOx, etc.
(5) Others	Plants Generating Clean Energy, etc.

Source: Hiroshi Kamada, Tsukuba University

Chart 4: The 7TH Technology Foresight Survey: Technological Challenges to GM Plants

Technological Challenges	To be Commercialized by:
Development of an assessment method that is understood by consumers and reviews the safety of GM crops from food and environmental perspectives.	2011
Development of foods that prevents degradation in the anti-oxidant function, cerebral function, and mastication function, all of which are characteristics of the aged, thereby supporting a healthy aging society.	2012
Widespread proliferation of GM crops with improved yields, disease resistance, and freezeresistance in Japan.	2013
Development of GM foods containing functional elements that prevent hypercholesterolemia, high blood pressure, hay fever, etc.	2013
Commercialization of low-temperature-resistant plants with molecular mechanisms transmitting information (from reception of external information such as low temperatures to expression of properties) being determined.	2014
Social recognition and widespread proliferation of GM crops that can be cultivated without agrochemicals.	2015
Development of commercial species of needle-leaf trees with useful properties (e.g., cedar producing no pollen) through applications of new technologies to forest tree breeding (e.g., gene manipulation and cell fusion).	2015
Widespread proliferation of functional foods that prevent life-style related diseases in accordance with the constitutional tendencies of individuals.	2015
Commercialization of GM plants and microorganisms that can remove environmental pollutants such as NOx.	2018
Commercialization of breeding technology for drought-resistant and salt-resistant plants in order to stop desertification.	2018
Development of crops having the properties of fixing nitrogen in the air and phosphoric acid in the soil (environmental conservation technology for reducing fertilizer application).	2018
Commercialization of plants for fuel that accumulate high concentrations of hydrocarbons.	2019

Source: The Science and Technology Foresight Center

of the first-generation GM plants are environmental stress-resistant plants, which ensure a certain amount of yields even in an unfavorable environment for cultivation (climate, soil, etc.). As for non-food applications, development of plants that can rehabilitate or purify the environment, or generate energy (plants producing fuel alcohol, etc.) is taking place.

However, commercialized items are still limited to part of the first-generation and the second-generation GM plants. The National Institute of Science and Technology Policy (NISTEP) foresights that GM plants will be developed and commercialized as shown in Chart 4.

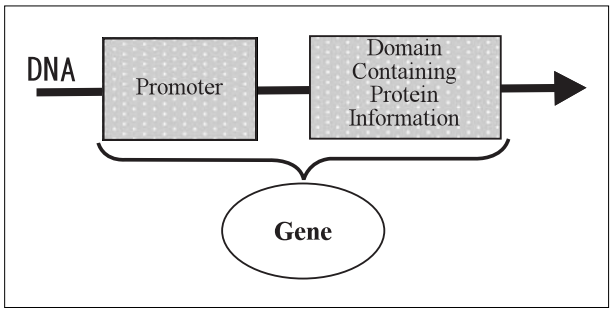
2.3 Current Trends in R&D in Japan

2.3.1 Technology for Creating GM Plants

(1) The Structure of DNA

In general, organisms transmit their gene information by DNA (deoxyribonucleic acid). There is a domain called "gene" in part of the base sequence of DNA, and this domain is comprised of a promoter, a domain controlling gene expression, and a domain containing protein information (see Chart 5). While the base sequence of each domain containing protein information is common to each corresponding protein among the same species of organisms, promoters controlling gene expression vary with the species of organisms, expression periods, expression sites, and the amount of expression. This is why each organism and site creates different types of protein. It is thus possible to create a specific type of protein in a site of a target organism by combining promoters and domains containing the proper protein information.

Chart 5: Structure of DNA



Source: The Science and Technology Foresight Center

(2) Genetic Modification Technology for plants

The genetic modification technology for plants can be broadly categorized into gene transfer technology, gene expression regulation technology, and Genetic Modified Organisms(GMO) screening technology.

①Gene Transfer Technology (technology for transferring target genes to plant cells)

Gene transfer technology can be typified by the "Agrobacterium-mediated Transformation"(a method where useful genes are transferred to plant cells by means of the infectivity of soil bacteria to which those useful genes are transferred), and the "Particle Bombardment"(a method where useful genes adhered to fine gold particles, etc., is driven into plant cells at supersonic speeds). These two methods are practiced worldwide.

Unlike animal cells, however, plant cells are covered with cell walls and are relatively small – a feature that makes gene manipulation more difficult. Moreover, gene transfer is extremely difficult for some species of plants. Efficient technology for transferring genes to plant cells is thus required. As for development of gene transfer technology in Japan, a project subsidized by Bio-oriented Technology Research Advancement Institution (BRAIN), and led by the engineering research course of the graduate school at Osaka University, has developed technology for piercing a fine hole in a plant cell wall through the use of short-wavelength pulse laser beams. This technology is expected to develop into chromosome manipulation by mega base unit and direct gene transfer into organelles.

②Gene Expression Regulation Technology (technology for regulating the gene expression characteristic of each gene)

In general, promoters regulate gene expression, and promoters that express genes in specific parts of plants are being identified and isolated.

Technology for controlling the functions of specific genes is typified by the "Antisense Method "(a method where the expression of target genes are controlled by expressing genes that have sequences complementary to those of the target

genes). In addition, the "Co-suppression Method" is used for creating oleic-acid-rich soybean (a method that utilizes the phenomenon that the expression of target genes is considerably regulated when the target genes themselves are transferred to plant cells).

③GMO Screening Technology (technology for screening GM plant cells)

In screening GMO, antibiotic-resistant genes of microorganisms, along with target genes, can be transferred to plant cells as an indicator. Nippon Paper Industries, however, developed an alternative technology, namely the "MAT Vector System", because GM foods containing antibiotic-resistant genes of microorganisms may arouse concern among consumers. In addition to target genes, this method transfers genes inducing morphogenetic abnormalities; GM cells are visually screened out, and those genes inducing morphogenetic abnormalities are then removed from DNA.

Those gene transfer technologies mentioned above are based on the premise that target genes are transferred to chromosomes on a random basis. On the other hand, homologous recombination is commonly used for transferring specific genes to designated places in genomes – i.e., target genes are modified, capitalizing on the phenomenon where recombination takes place among DNA, the sequences of which are identical with each other. The establishment of this technology is expected to lead to the creation of useful crops by regulating the functions of specific genes, and more detailed analysis of gene functions. In particular, the technology is most needed for higher plants. Homologous recombination can be applied to Physcomitrella patens, a kind of moss, and this particular technology is being improved for applications for higher plants. However, there are many hurdles to surmount.

2.3.2 Patents Relevant to Genetic Modification Technology

Of the technologies necessary for the development of GM plants described in (2) of the section above, all the useful technologies are protected by patents. Research institutes and private enterprises engaged in the development of GM plants on a commercial basis should thus be licensed under relevant patents belonging to other research institutes, etc. Chart 6 shows the major patents in this particular field.

Foreign companies (e.g., nursery companies, agrochemical companies, etc.) hold major patents such as those for: the "Agrobacterium-mediated Transformation" and the "Binary Vector Method", both of which are indispensable for commercialization-oriented R&D; gene transfer methods such as the "Particle Bombardment"; methods for regulating expression of transferred genes (promoters, etc.); and methods for screening antibiotic-resistant genes, etc. Most of these patents were filed in the middle of the 1980s, all of which will be off-patent within the next few years. It is thus very important to take advantage of these opportunities in order to improve existing technologies, foster groundbreaking studies that may lead to the development of advanced technologies such as homologous recombination, and explore useful genes.

In Japan, several methods for transferring genes to the cells of monocotyledonous plants (rice, etc.) have been developed; the application of gene transfer technology to these plants using "Agrobacterium-mediated Transformation" remains difficult. Moreover, some epoch-making screening methods such as the "MAT Vector System" mentioned earlier have been developed as well.

Therefore, as far as the existing technologies are concerned, development of GM plants on a commercial basis is expected to become easier by making full use of practical domestic patents and technologies whose patents will expire shortly. For instance, joint researches among universities that isolate useful genes, public research institutes that hold patents for gene transfer technology and the like, and municipal experimental research institutes that actually develop new varieties would facilitate development of GM plants on a commercial basis.

Moreover, participation of private enterprises is indispensable for commercializing basic researches such as researches on the plant genome. For this reason, there is a need to promote R&D among non-food industries in order to stimulate R&D of private enterprises.

Specifically, priority areas in R&D should be broadened (e.g., GM plants producing substances such as industrial materials), so that private enterprises in various sectors can make inroads. Through these efforts, R&D systems for common basic technologies can be strengthened.

2.3.3 The Present Situation of and Future Approaches to R&D in Japan

Public research institutes and universities in Japan have been relatively active in pursuing basic researches in gene expression, as well as in the

Chart 6: Foreign Technology and Domestic Alternative Technology Relevant to the Development of GM Crops

Technology	Foreign Technology		Domestic Alternative Technology, etc.	
	Designation	Patent Holder (Expiration Year)	Designation	Patent Holders / Developers (Expiration Year)
Methods for Transferring Genes	Agrobacterium-mediated Transformation	Max-Planck Institute (2004)	Genetic Transformation of Monocotyledonous Plants Using Agrobacterium	Japan Tobacco (2013)
			Ultra Rapid Genetic Transformation of Monocotyledonous Plants	National Institute of Agrobiological Sciences (2019)
	Binary Vector	Mogen (Astra Zeneca) (2004)		
	Electroporation-mediated Transformation	Ciba-Geigy (2005)	Polycation-mediated Transformation	National Agriculture Research Center (2014)
	Genetic Transformation of Protoplast of Plants (PEG Method)	Novartis (2005)		
	Particle Bombardment	DuPont (2011) Agracetus (2007)	Particle Bombardment	Rehbock Commerce and Industry (2012)
Methods for Regulating the Expression of Transferred Genes	CaMV35S	Monsanto (2004)	PR1 Promoter	No Patent Applicable National Institute of Agrobiological Sciences
	Ubiquitin Promoter	Mycogen Plant Science (applied for on May 17, 1989, unregistered)	Retrotransposon Promoter	No Patent Applicable National Institute of Agrobiological Sciences
			LHCP II Promoter (Photo Synthesis-Related Genes)	National Institute of Agrobiological Sciences (2010)
			Soybean Green Spot Virus Promoter	National Institute of Agrobiological Sciences (2009)
	Basic Patent for Antisense Technology	State University of New York (2004) Zeneca (2007)		
Methods for Screening GMO	Kanamycin-Resistant Genes	Monsanto (2004)	MAT Vector System	Nippon Paper Industries (2015)
	Hygromycin-Resistant Genes	Eli Lilly and Company (2004)		

Source: The Agriculture, Forestry and Fisheries Research Council

exploration of useful genes through functional analyses of plant genes and the collection of various genes from microorganisms and other organisms. However, there have not been many cases where these basic researches lead to the development of GM plants.

As rice is the chief staple diet in Japan, national research institutes place emphasis on R&D of rice. In addition to rice, meanwhile, municipal experimental research institutes have been conducting researches on their specialty crops. The recent trend, however, has been to shift from crops to flowers and ornamental plants – commodities gaining wider market acceptance as GM plants. Considering the poor marketability of GM foods in the future, nursery companies and food companies alike are switching their R&D targets from crops to flowers and ornamental plants, exploring new colors and long shelf life. Moreover, a growing number of companies are pulling out of the GM-food business for fear that engaging in the development of GM foods may blemish their corporate image.

That said, ensuring a stable supply of quality food and extending people's healthy life expectancy continue to be critical issues for the government. R&D of GM plants and foods, both of which are expected to contribute to solving these issues, should thus be pursued in the future. For this reason, the government needs to consider how it should promote R&D of GM plants and foods.

The following are the possible approaches to R&D with domestic production in view:

i) Development of disease-resistant, insect-resistant, and high-yielding crops that contribute to stable food production
ii) Development of quality crops (eating quality, processability, etc.) that can compete against imported crops
iii) Development of new crops (functional foods) with particular emphasis on functional elements

As an approach to R&D efforts with international cooperation in view (e.g., solution of the food problem in developing countries), the following can be suggested in addition to item i) mentioned above:

iv) Development of crops having properties such as environmental-stress-resistance (drought-resistance, salt-resistance, etc.)

In addition to R&D intended for crops, development of plants with the aim of solving environmental concerns and energy problems is also important.

In creating a market for GM plants step by step, it may be appropriate to start with the development and commercialization of GM plants having the functions of improving health and treating diseases – commodities that can be accepted by consumers with relative ease.

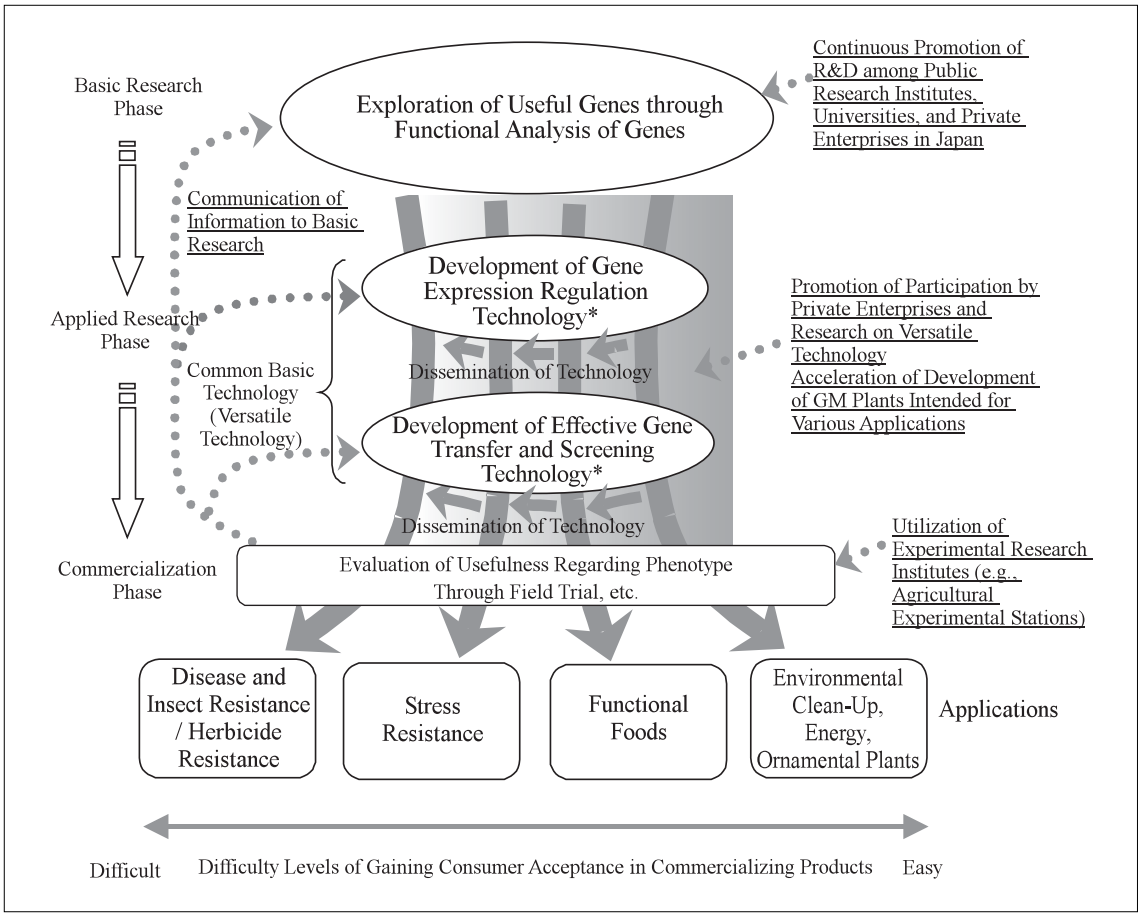
Thanks to rapidly progressing researches on the plant genome centered on rice, a growing number of useful genes that provide crops with designed properties are being identified and isolated; these accomplishments should immediately be linked with development of new varieties. To this end, there is a need to create a system through which GM plants, based on the accomplishments of genome researches, are developed and evaluated in a timely manner (e.g., a partnership between basic research institutes that carry out genome researches and field research institutes such as agricultural experimental stations that develop and evaluate GMO).

2.3.4 Measures for Promoting R&D in Japan

Chart 7 illustrates measures for promoting R&D in Japan. As mentioned earlier, national research institutes, universities, and part of private enterprises have been relatively active in pursuing basic researches in gene expression as well as in the exploration of useful genes through functional analyses of plant genes and the collection of various genes from microorganisms and other organisms. It is important to maintain this momentum by aggressively introducing state-of-the-art analysis technology such as bioinformatics and systems biology.

Versatile technologies such as gene expression regulation and gene transfer are the basis for developing GM plants, and hence they can be used for creating various GM plants – a feature that makes their patents extremely useful. To take a look at the recent trend in R&D efforts outside

Chart 7: Measures for Promoting R&D of GM Plants



* Advanced basic research in the field of molecular biology should be promoted in order to make a breakthrough in common basic technology - i.e., technologies for gene expression regulation, gene transfer, and screening.

Source: The Science and Technology Foresight Center

Japan, a growing number of private enterprises emphasize patent strategies in their R&D to develop these kinds of useful technologies.

The situation in Japan exhibits sharp contrast to this trend, as mentioned earlier: due in large part to consumer preferences for safer foods and corporate-image-related issues, private enterprises such as nursery companies and food companies are, and will be, facing difficulties in putting corporate resources into R&D of GM plants intended for foods (subsidizing these companies may not be an effective measure in view of the negative images inherent in GM plants).

In addition to promoting R&D efforts among national research institutes and universities, therefore, there is also a need to encourage private enterprises in various industrial sectors to participate in the development of GM plants (e.g., plants designed for environmental rehabilitation, energy production, and ornaments), thereby pursuing applied researches to establish common basic technology.

In Japan, it is rarely the case that GM plants developed in laboratories reach a field trial phase. Indeed, sufficient data on the utility and practicality of isolated genes have yet to be accumulated through field trials. With this as a backdrop, research functions at the demonstration phase should be strengthened in order to study the feasibility of GM plants that have been developed, evaluate the usefulness of possible applications, and gather applicable information for the benefit of basic researches.

2.4 Global Trend Towards the Assurance of Safety

2.4.1 Concepts of Safety in the World

There has been a lot of talk about the safety of GM plants and foods worldwide over the past several years. The following are the major concepts of safety widely practiced across the world:

— Substantial Equivalence
A concept that serves as a standard for evaluating the safety of food: GM foods are evaluated in comparison with conventional foods that have been up to now consumed safely.
— Traceability
A concept that traces and identifies every aspect of the processes for cultivating, producing, and handling foods.
— Familiarity
A concept that serves as a standard for evaluating current safety levels from an environmental perspective: appropriate safety levels are secured based on existing findings and experience.

OECD, WHO, CODEX, and the Conference of the Parties to the Biodiversity Treaty set forth international regulations and standards for GM plants and foods.
CODEX, to which 165 countries are participants, is currently discussing international standards for the labeling of GM foods. As for the evaluation of the safety of GM foods, a biotechnology special session chaired by Japan is discussing issues such as "the principle in risk analysis of biotechnology-derived foods" and "the guidelines for evaluating the safety of foods derived from GM plants." CODEX approved an interim report on these two issues in a meeting held in July 2001; the final report is now being prepared for presentation at a general meeting scheduled in 2003.
With regard to possible environmental impacts, the Conference of the Parties to Biodiversity Treaty, to which more than 130 countries including Japan are participants, adopted the "Cartagena Protocol on Biodiversity" in January 2000. As far as the first exports of GMO (e.g., items to be directly released into the environment such as seeds) are concerned, this protocol mandates that exporting countries provide importing countries with the necessary information regarding GMO to be exported; import and export procedures can be accomplished only after importing countries and exporting countries have agreed with each other.

2.4.2 Trends in the U.S. and EU

(1) The United States
EPA, USDA, and FDA regulate GM plants and foods in accordance with the "Coordinated Framework for the Regulation of Biotechnology," which was set forth in 1986. However, there are no legal restrictions on the labeling of GM foods.
Deregulation of GM foods, a trend that was once dominant in the U.S., began to lose momentum in about 1999 in response to changing consumer awareness. "The Food and Biotechnology Initiative," which was announced by the Executive Office of the President in May 2000, sets forth the guidelines for tightening regulations based on scientific grounds, and for providing consumers with information on foods and biotechnology. FDA also announced a draft of the guidelines in January 2001 for in-advance applications regarding GM crops and their labeling. New concepts such as identity preserved handling are likely to be adopted in the U.S.

(2) EU
EU regulates GM plants and foods based on Directive 220/90: Release of GMO into the Environment. Premarketing safety review and labeling are thus compulsory for GM foods. Any foods containing GM foods should indicate accordingly on labels, along with allergens and ethical issues. EU is now discussing the introduction of laws and regulations including the concept of traceability in a bid to revise Directive 220/90, the feasibility of which remains uncertain because of issues such as the limitations associated with scientific evaluation and traceability.

2.5 The Assurance of the Safety of GM Plants and Foods, and Communications with Consumers

2.5.1 The Administrative Framework for Assuring Safety

In Japan, the environmental impact of GMO plants and their safety as food are evaluated in line with international concepts such as familiarity and substantial equivalence mentioned earlier.

As for safety issues relevant to the environment, the Ministry of Education, Culture, Sports, Science and Technology sets the guidelines for the basic research phase (i) closed-system greenhouse experiment, ii) non-closed-system greenhouse experiment), and the Ministry of Agriculture, Forestry and Fisheries, the guidelines for the industrial application phase (iii) experiment in a simulated environment). Cultivation experiments are conducted following these three phases.

i) Closed-System Greenhouse Experiment
Experiments conducted in a closed glasshouse: basic characteristics of GM plants – whether or not transferred genes are passed on to later generations, or toxic substances are produced – are determined.

ii) Non-Closed-System Greenhouse Experiment
Experiments conducted in a glass-mesh-house exposed to the open air: characteristics of pollens and seeds, and influences on soil microorganism are determined in a greenhouse equipped with a concrete floor and meshes.

iii) Experiment in a Simulated Environment
Experiments conducted in an isolated field encircled by fences, and equipped with an incinerator and a washing place: expression of transferred genes, influences on other organisms, and influences of airborne pollens on the environment are determined.

For use of GM plants in food, the Ministry of Health, Labour and Welfare mandates safety reviews based on the Food Sanitation Law. As for applications to fodder, the Ministry of Agriculture, Forestry and Fisheries sets guidelines.

2.5.2 Environment Impact Assessment

Environmental impact of GM crops is determined based on "The Guidelines for Use of GMO in Agriculture, Forestry and Fisheries," which was set forth in line with framework concepts such as familiarity. Examination results of compliance with the guidelines and updated information on cultivation experiments are announced through the Ministry's homepage or other media in a timely manner.

In order to make environmental impact assessments absolute and universal, these guidelines incorporate every assessment item that is considered necessary based on scientific grounds. The assessment items are reviewed from time to time through additional experiments to reflect new scientific findings. A group led by the National Institute for Agro-Environmental Sciences takes charge of these environmental impact assessments.

It is necessary to accumulate Japan's own assessment data because the results of assessments conducted in other countries, the environment of which differs from that of Japan, cannot be applied as they are. It is also important to continue monitoring environmental impact over the long term, assuming that large-scale commercial plantation of various GM plants will take shape in Japan in the future. Environmental impact assessments involve a wide range of studies such as botany, ecology, microbiology, entomology, pedology, and meteorology. Partnership with researches in these fields should thus be strengthened.

2.5.3 The Assurance of the Safety of GM Plants as Food

(1) Safety Reviews
Safety reviews of GM foods became mandatory in April 2001. Production, import, and handling of GM foods without safety reviews were banned in accordance with the "Standards for Food and Food Additives," which is based on the Food Sanitation Law; any violation of this arrangement may result in penalties. The Pharmaceutical Affairs and Food Sanitation Council, which is made up of experts in relevant fields, reviews detailed information and data on safety assessments to be provided by developers of GM plants. Specific items to be assessed are: the safety of transferred genes; toxicity of protein produced by transferred genes; the presence or absence of allergens; probabilities of transferred genes contributing to the production of toxic substances; and probabilities of transferred genes changing the elements of subjects dramatically. The results of assessments are announced through the Ministry's homepage or other media such as official journals in a timely manner.

As in the case of environmental impact

assessments, the standards for safety reviews are based on the latest scientific findings; they should thus be revised from time to time as new findings such as those on the mechanisms of allergy developments accumulate in the future.

(2) Labeling and Monitoring Inspections

Proper indications on labels and arrangements such as monitoring inspections are mandated in Japan in order to ensure appropriate handling of GM foods based on safety reviews.

In April 2001, the Ministry of Agriculture, Forestry and Fisheries set forth "The Law Concerning Standardization and Proper Labeling of Agricultural and Forestry Products (JAS)," and mandated GM foods have indications of their ingredients on labels in order to support consumers in selecting GM foods. In view of ensuring public heath, the Ministry of Health, Labour and Welfare took the same measure based on the Food Sanitation Law.

Designated crops are soybeans, corn, potatoes, coles, cottonseeds, and processed foods made from these crops, containing residual modified DNA or its by-product protein (soybean- or corn-derived foods). These crops are broadly categorized into: i) GM foods produced, handled, and managed separately; ii) GM foods produced, handled, and managed together with other non-GM foods; and iii) Non-GM foods produced, handled, and managed separately. Category i) and category ii) need to be indicating accordingly on labels, while category iii) may follow the instructions on a voluntary basis (non-compulsory).

"Identity Preserved Handling System (IP Handling)" is a system where proper management of specific items such as non-GM crops throughout production, handling, and processing is guaranteed by documents, etc. Absence of this management can be termed "Non-IP Handling." It is difficult to prevent GM crops from being mixed into materials; the percentage of GM crops to materials should be less than 5%, according to the regulations in Japan. Although all GM crops currently on the market have been proved to be safe, IP Handling continues to be indispensable for supporting consumers in selecting commodities.

Monitoring inspection, on the other hand, are widely practiced by quarantine stations and municipalities in order to prevent unidentified GM foods from being distributed in the domestic market, and to verify proper labeling of GM foods. In order to unify inspection methods for detecting "GM foods without safety reviews," the Ministry of Health, Labour and Welfare issued Notification 158: Inspection Methods for Genetically Modified Food.

2.5.4 Communications with Consumers

While genetic manipulation technology and the development of GM plants continue to advance, concern is growing among consumers about the safety of food. There is thus a need to create a social consensus through sufficient communication with consumers.

The results of "The Consciousness Survey Regarding the Commercialization of GMO," which was carried out by the Society for Techno-innovation of Agriculture, Forestry and Fisheries (STAFF) as a project commissioned by the Ministry of Agriculture, Forestry and Fisheries, shows that more than 50% of both food manufactures and retailers believe that GM foods are not well accepted by consumers. The reasons mentioned by more than 80% of food manufacturers are: mass media is generating widespread concern among consumers; and public institutes are not publicizing the safety of GM foods in a sufficient manner. Administrative bodies and other related organizations should thus communicate with consumers aggressively.

In a bid to encourage citizens to participate in science and technology, and to meet their needs, STAFF held "The Consensus Conference on GM Crops" from July to November 2000 at the request of the Ministry of Agriculture, Forestry and Fisheries. A consensus conference is a meeting where non-specialist citizens discuss given topics based on advice from specialists in order to build a consensus on those topics. Specialists and administrative bodies should cooperate in continuing this kind of important approaches in the future.

Through a series of on-line forums, the Ministry of Economy, Trade and Industry is releasing the results of discussions about the next R&D programs, while widely soliciting opinions from

viewers. Research topics on GM plants are addressed in "The Creation of Recycling Industrial Systems Based on Bio-functions," one of the themes of the forums.

In response to a growing demand for gene-splicing experiments at high schools and other educational establishments, the Ministry of Education, Culture, Sports, Science and Technology plans to institute "Recombinant DNA Experiments for Educational Purposes" exclusively for safe experimental subjects; the purpose is to disseminate knowledge and facilitate the understanding of gene splicing.

In addition to the approaches mentioned above, administrative bodies and municipalities are releasing the results of relevant safety tests through their homepages, preparing PR brochures, and holding various seminars. There is also a need to create a comprehensive database covering a variety of information accumulated at ministries and research institutes (e.g., research topics, cultivation status, safety assessments, test results, and information on researchers, seminars, consensus conferences, etc.), so that information required can be searched in a cyclopedic form.

2.6 Conclusion

As far as Japan's current approaches to R&D of GM plants and foods, and the assurance of their safety are concerned, the following issues surface as subjects to be addressed in the future:

- The establishment of common basic technology such as gene recombinant is indispensable for commercializing achievements of basic researches on the plant genome, etc. While private enterprises are expected to play a major role in establishing this kind of technology, the present situation is such that they are having a hard time participating in R&D because concern is growing among consumers about the safety of GM foods. One effective option offered at this time, therefore, is to encourage private enterprises in various industrial sectors to participate in the development of GM plants (e.g., plants designed for environmental rehabilitation, energy production, and ornaments), thereby pursuing applied researches to establish common basic technology.
- In commercializing GM foods, those provided with the properties of contributing to health and treatment of diseases should be developed first – i.e., socially important items that can be easily received in the market.
- Researches on safety reviews (e.g., researches on experimental medicine such as those on food allergies, and researches corresponding to new scientific findings on environmental impact) should be continued.
- A system to indicate safety levels on labels should be improved, and administrative bodies and other related parties should communicate actively with consumers in order to establish a social consensus.

Acknowledgements

This report was prepared based on the lecture delivered by Professor Hiroshi Kamada at Tsukuba University on March 28, 2001 ("The Present Situation of Researches on GM Plants and Foods and the Assurance of Safety") and the results of surveys we conducted.

We would like to express our gratitude to Professor Kamada for his advice and provision of related materials, both of which contributed substantially to this report.

3

Trends in Research and Development of Lithography Technology for Next-generation LSIs

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3.1 Introduction

On April 12, 2001, the world's first EUV (extreme ultraviolet) lithography tool for the next-generation LSIs, which allows semiconductor manufacturers to print circuit lines below 0.1μm (100nm), was revealed at the Sandia National Laboratories of the U.S.

This tool was developed in collaboration with the U.S. DOE (Department of Energy) laboratories (Sandia, Laurence Berkley and Laurence Livermore) and a consortium called EUV LLC, which consists of Intel, Motorola, AMD, Micron Technology, Infineon Technologies (Germany) and IBM.

The tool currently allows mass production in accordance with the 0.07μm (70nm) rule, and is expected to support 0.03μm (30nm) in the future. Specifically, the current operating frequency of 1.5GHz with the Pentium 4 processor is expected to reach 10GHz in 2005 to 2006.

Japan's semiconductor technology, which conventionally developed with DRAMs as the technology driver, maintained its top position in terms of device scaling throughout the 1980s and the 1990s. This success has been made possible mainly due to the fact that Nikon and Canon, both of which have excellent optical technologies, have maintained their leading positions in the field of steppers (projection printing tools for circuit patterns) for LSIs.

In the late 1990s, the United States regained the world's top position from Japan in semiconductor share with its designing technologies represented by the MPU technology. Additionally, it has launched a campaign aimed at also capturing the top position in lithography technologies, which are expected to play the principal role in manufacturing technologies, in order to solidify its position in the next-generation LSIs market.

This article analyzes the United States' EUV lithography technologies, and touches upon Japan's course of direction in technological development.

3.2 Situation by Country in Lithography Technologies

3.2.1 Current Status of Lithography Technologies

Since the 1980s, Japan has boasted its overwhelming strength in the stepper market for semiconductor manufacturing, with Canon and Nikon maintaining approx. 30% and 40% shares, respectively. In the past few years, however, ASML of the Netherlands has made significant progress with the backing of Philips and Carl Zeiss, and in fiscal 2000, it overtook Nikon to capture the top share, 40%-plus. Thus, Japan is being overwhelmed from attacks by the U.S. and European powers not only in the next-generation LSIs market but also in the present-generation market.

Even in the development of existing optic-based lithography technology, Japan is being overtaken by ASML in terms of greater lens diameters and higher NAs (numerical apertures). This is largely owing to the fact that Schott Glas supports Carl Zeiss lenses with its material handling technique. Schott's expertise in optic fiber production is used in forming lens material crystals; thus, technologies that are not based on the conventional method of manufacturing camera lenses are being tested.

Chart 1: Roadmap of Lithography Technologies

	Light Source	Wavelength (μm)	Introduction timing (year)
Optical method	KrF	0.248	Currently mass-produced
	ArF	0.193	2000 ～
	F_2	0.157	2003 ～
Electron-beam projection	EPL	Variable	2006 ～
Extreme ultraviolet method	EUV	0.0134	2008 ～

Source: Data by Ohmi Lab, New Industry Creation Hatchery Center, Tohoku University

3.2.2 Roadmap of Lithography Technologies

Since line widths have been decreasing in the manufacture of LSIs, it was formerly thought that lithography technologies would be developed according to the roadmap indicated in Chart 1.

3.2.3 Situation in Japan

In Japan, research and development efforts for optical methods are being made from ArF to F_2, in accordance with the schedule indicated above. The industry leader Nikon is proceeding with the development of the F_2 method, and for the development of a post-optical generation method, it has chosen EPL to be developed in cooperation with IBM.

3.2.4 Situation in the United States

In the United States, however, the industry has concluded that it would be difficult to manufacture large crystals of CaF_2, which is one of the lens materials, in developing the F_2 method, and shifted to the EUV method. The decision was based on the grounds that if an F_2-based stepper was manufactured with the existing method (pulse oscillation), it would require tens of CaF_2 crystal lenses, each measuring 30cm in diameter and 20cm in thickness, in order to reduce the high energy density. It was judged that the F_2-based stepper would not be feasible because at that size, the production yield of the crystal would be very low, and the CaF_2 crystal, which has relatively low mechanical strength, would be deformed by its own weight.

EPL was another possibility for a next-generation method. However, EUV was chosen since with EPL, it would be difficult to manufacture a mask and the throughput would be lower than EUV. Also, it is said that the technology developed for a reconnaissance satellite was used in developing the EUV method of condensing beams. This implies the transfer of a military technology.

The course of direction of the whole U.S. semiconductor industry has become clear as IBM, which was developing the EPL technology in cooperation with Nikon, joined EUV LLC in March this year.

3.2.5 Situation in Europe

The European semiconductor industry is adjusting its stride to the United States as Infineon Technologies (Germany) has joined EUV LLC, and ASML has withdrawn from the development of EPL and starting cooperating with EUV LLC. However, the European industry slightly differs from U.S. in that it has not given up on the possibility of the F_2 method. For example, the ASML-Carl Zeiss-Schott alliance has developed a lens with a 0.9 NA for the manufacture of CaF_2 crystals with the F_2 method. The European industry is also characteristic in that it has superior crystal researchers in the former Eastern European and former Soviet Union countries and material technologies based on the latest optical fiber technologies, neither of which are found in the U.S. industry.

3.3 Course of Direction in Next-generation Lithography Technologies

3.3.1 Problems of the EUV Technology

As described above, the U.S. and European strategies are all being oriented toward EUV as the next-generation lithography technology. However, this does not mean that the EUV method is the favorite next-generation lithography technology for the following reasons.

Chart 2: Photon Energy

	Wavelength (μm)	Frequency (PHz)	Photon energy	
			eV	Ratio to KrF
EUV	0.0134	22.4	92.53	18.506
F_2	0.157	1.910	7.90	1.580
ArF	0.193	1.553	6.42	1.285
KrF	0.248	1.209	5.00	1.000

Source: Data by Ohmi Lab, New Industry Creation Hatchery Center, Tohoku University

Chart 3: Band Gaps of Materials

Material	Band gap
CaF_2	9.41eV
Al_2O_3	8.95eV
SiO_2	8.95eV

Source: Data by Ohmi Lab, New Industry Creation Hatchery Center, Tohoku University

(1) High energy damage

Since EUV is a microwave (0.0134μm), a single photon can generate high energy of 92.5eV (Chart 2).

As indicated in this table, EUV generates energy 18.5 times higher than the existing KrF. This level of energy is far greater than the band gap of any lens material or optic material shown in Chart 3, and will excite electrons that contribute to the coupling to damage the material. To solve this problem, a miller with high reflectivity is used to condense light. However, any lens-based method will cause light to directly enter the mask surface, even if a miller is used. Since a multi layer film of MoSi is used in the mask, it is highly likely that it will generate high temperature as it receives high energy.

Therefore, the materials constituting the mask and the device may deteriorate, leading to an increase in the overall cost.

(2) Precision of the mask

Since the mask has a multi layer structure, it requires very high precision and the throughput in the manufacture of the mask will remain low.

(3) Contamination from the EUV light source

Metal vapor may adhere to the optical system.

3.3.2 Possibility of the F_2 Method

Although the United States has almost abandoned the F_2 method, if the light source for the present pulse wave method is converted to a continuous wave system, the sharp power peak can be controlled and the present performance can be achieved with a smaller CaF_2 crystal by reducing the load on the optical system. Since the largeness of CaF_2 crystals that are formed is the biggest problem of this method, if an F_2 excimer laser capable of continuous oscillation is developed, it will be possible to develop a system optimized for mass production. The line width can be dropped to 0.05μm using a 0.9 NA lens.

3.3.3 Possibility of the Electron Ray Method

Although the electron ray method is increasingly considered unsuitable for the next-generation lithography technology both in the U.S. and Europe, this method has advantages that are not found in the optical and EUV methods. With the electron ray method, a higher NA lens will be used in response to miniaturization. The higher the NA, the shallower the focal depth becomes. In other words, the range for adjusting the focus in the vertical direction becomes smaller. Even with the EUV method, images are formed on the wafer, and, therefore, a similar phenomenon occurs.

However, this problem can be solved by directly drawing electron beam. If the devices developed in the future have the dimensional structure, the electron beam method will likely attract strong attention as a lithography technology capable of solving this problem

3.4 Conclusion

If Japan follows the United States and Europe in adopting EUV as the next-generation lithography technology, it will be inevitably disadvantageous. However, since the F_2 method and the electron ray method also have many advantages and possibilities, it will not be correct to regard them negatively.

In particular, Japan is taking the dominant lead in the development of continuous-oscillation excimer laser technologies, and has been the most advanced in application technologies for electron rays. In addition, it has made research efforts in X-

ray exposure technologies, which is not explained in this article.

Concerning research and development of semiconductors in the United States, business, academic and governmental collaborations such as EUV LLC, and business and academic alliances such as Stanford University's CIS (Center for Integrated Systems) are effectively functioning for the development of next-generation LSI technologies.

Even Japan can seize the chance for victory if it implements next-generation semiconductor and lithography strategies that can answer the questions: what is the mainstay of next-generation LSIs (commodity products like conventional memories or system LSIs for diversified-item, small-volume production), and what is the form of devices that are being increasingly miniaturized (still the planar structure or the 3-dimensional structure).

LSI technology is the core of data processing and communications technologies, and it is the technology that Japan needs to control in order to maintain its top position in both economy and technology given that IT technologies are spreading into every sphere of society.

* **Notable Trends**

AMSL's Acquisition of SVG to Fortify the U.S.-Europe Alliance

On May 3, the Bush administration announced that it approved ASML's plan to acquire SVG in California.

It appears that SVG is playing an important role in helping EUV LLC develop a mass production machine for EUV. The company is known as the main supplier of steppers for Intel. ASML had submitted the acquisition plan (announced in October 2000), and the U.S. government committee CFIUS (Committee on Foreign Investment in the United States) conducted an investigation from March 7.

Since SVG has an agreement with the military, it was thought that the administration would disapprove the plan from a security standpoint. Thus, the decision of the Bush administration has drawn much attention.

With the latest movement, the strengthening of the U.S.-Europe coalition in the semiconductor industry is becoming a reality.

* **Sources:**

Center for Integrated Systems (CIS)
Stanford University

Ohmi Lab, School of Engineering, Tohoku University

4

Raging Computer Viruses

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4.1 Introduction

Around July and August 2001, two types of viruses*1—SirCam and CodeRed/CodeRed II—were running rampant. Developed for malicious purposes, both are highly infectious and capable of generating severe symptoms (damage from infection).

Malicious programs such as viruses, worms, and Trojan horses*1 are causing increasingly serious damage as they become more sophisticated year after year and as they spread more quickly via the highly prevalent Internet.

This report summarizes recent trends in computer viruses, with emphasis on the above two viruses.

4.2 Virus overview

4.2.1 SirCam

(1) Characteristics

SirCam, a virus/worm that made its first appearance on July 17, 2001, is distributed via e-mail attachments. When a recipient opens an infectious attachment, the virus program is loaded onto the PC to start the following activities.

SirCam sends e-mails to e-mail addresses registered in the address book of MS Outlook/Outlook Express and in files included in the Internet Temporary Files folder of the infected system. Each message has an attachment that contains a document or an image file randomly selected from the PC's My Document folder as well as a copy of the virus program. The title of each message is equivalent to the one for the file selected as its attachment, while the body is written in English or Spanish. The messages are transmitted by the worm itself without leaving any records on the e-mail software, so that the user often does not notice it.

In addition, this virus does the following damage.

1) There is a certain chance that SirCam may delete all files on the C drive on October 16.
2) There is a certain chance that SirCam may fill up the vacant hard disk space at startup of PC.

Due to a bug in the program, SirCam does not work on Windows NT/2000. In addition to this, anti-virus measures, such as removing viruses at the server level, which major businesses and some ISPs have taken in response to past virus threats, prevented this worm from being as widespread as Love Letter (also known as "I love you"), a malicious program discovered in May 2000. Yet SirCam seems rampant among private users. The Information-technology Promotion Agency, Japan (IPA), the nation's virus watchdog organization, received a total of 1,441 reports (22% of them about actual infection) on SirCam from July 21 through August 20, 2001. In particular, in August, the number of filed reports hit a record high (1,257 reports) for a single virus within a month.

(2) Actual damage

By sending a randomly selected file as e-mail, SirCam exposes personal or corporate information to a third party. In fact, official documents of the FBI and the Ukrainian government have leaked out as a result of the virus. In Japan, computers at the prefectural governments of Nagano and Shiga were infected. According to an estimation by Computer Economics, Inc., an American IT research company, more than 2.3 million computers throughout the world will have become infected with SirCam by the end of August 2001, making individuals and enterprises lose as much as a total of $1 billion as the cost for disinfection, lost productivity, and so on.

4.2.2 CodeRed/CodeRed II

(1) Characteristics

Targeting Microsoft Windows NT/2000 machines, CodeRed is a worm that attacks computers by exploiting a security hole in the Web server program known as IIS (Internet Information Server). A security hole is a vulnerability that causes security problems such as having the security check function deactivated by certain operations.

Having emerged on July 13, 2001, the worm was particularly running rampant on July 19 as it infected an estimated 250,000 plus machines worldwide in 9 hours. Microsoft estimates that 6 million computers throughout the world have the risk of infection.

After entering a computer, CodeRed carries out the following operations.

- After two hours from the time of infection, the infected system starts to display a message,"Welcome to http://www.worm.com! Hacked by Chinese!", whenever the client PC accesses a Web page through the infected server, and this symptom lasts for eight hours.
- From the 1st to 19th every month, the virus carries out infectious attacks on computers with IP addresses it randomly generates.
- From the 20th to 27th every month, all infected servers launch a DDoS*2 attack against the White House's Web site.
- From the 28th to the last day of every month, the virus stops operation to pause.

The White House has changed its Web site address at July 19 to avoid DDoS attacks by CodeRed.

CodeRed became active again on August 1, and caused further damage. CodeRed Ver. 2, a variant of CodeRed, was discovered on July 19, followed by the more destructive version CodeRed II, found on August 4.

Instead of defacing Web pages, CodeRed II creates a backdoor (a secret entrance for hackers) on the infected server so that the hacker can take control of the server. In addition, as CodeRed II generates a wider range of IP addresses to define targets for attacks, infection may become more widespread.

CodeRed can also infect a private PC, as long as it has IIS installed. Even without infection, an attack by CodeRed can cause secondary damage such as network overloading and malfunction of routers and modems.

(2) Actual damage

As mentioned above, the White House's Web site was forced to change its address. CodeRed also did a lot of harm to many other Web sites including that of Federal Express in the U.S. and Hotmail, a free e-mail service provided by Microsoft, which either shut down the site or suffered interference with business due to overwhelming network traffic. In August 2001, infection spread to South Korea and China. In Japan, Tokyo Metallic Communications Corp. suffered a communication failure on their network presumably caused by this worm. IPA estimates several thousand systems nationwide have been infected with CodeRed as of August 6, 2001. Computer Economics projects that more than a million computers will be infected with CodeRed and its variants by the end of August, producing $2.6 billion worth of losses.

4.3 Trends in recent viruses

These two viruses, SirCam and CodeRed, have the typical characteristics of recent malicious programs.

File viruses such as SirCam are typically passed with files via e-mail, and start working only when the recipients open the files. However, SirCam uses a technique to transmit infectious e-mail by itself to dramatically increase its infection route.

SirCam also uses psychological tricks such as making believe the infectious e-mail is from a friend by using the address book of the infected PC and adding a random title to the infectious message and its attachment for disguise. Similar types of viruses including Love Letter are increasing these days.

On the other hand, a new type of virus has been discovered, that can be embedded in an e-mail message body to infect the e-mail recipient's computer even if no attachment is opened (VBS. Happy Time, etc.). Also found (on August 18, 2001, in Japan) was not a virus but a kind of malicious program that can infect and crash a system when someone just accesses certain Web pages. Aside

from the trend toward greater speed of infection, an increase of viruses that are passed through instant messaging (IM) services and mobile information devices, which have recently prevailed, is posing a new threat.

CodeRed is a virus designed to change Web pages without authorization and carry out DDoS attacks. This kind of virus is often used for political demonstrations, as in the case of the attack against the White House's Web site. Another obvious trend is the growth of viruses that, just like CodeRed II, intend to steal information by creating a hacking program on the infected computer. These new characteristics, which are not seen in conventional-type viruses, indicate a change in the nature of virus writers.

4.4 Developments in virus protection

A SirCam virus is loaded onto a system only when the virus program attached to an e-mail is opened. In addition, anti-virus software developers updated their virus pattern files*3 to prevent SirCam immediately after it was discovered. If uses had been more cautious, the virus would have been less rampant. On the other hand, when the security hole that CodeRed exploited for infection had been found on June 19, 2001, a patch (an additional program to fix bugs) to repair it was published by Microsoft together with an alert about the risk of a hacker making ill use of the vulnerability to take over servers. The security threat was obvious since, in early July, a program that can make an unauthorized entry into servers through the security hole was distributed online (it was removed afterwards). If every vulnerable computer had applied the patch, there would not have been any problems.

In practice, however, either of these viruses spread so widely that a great deal of harm was done. Here are possible reasons.

Many computer users, especially home users, are not well aware of the risk of viruses and the need for updating their virus pattern files.

Many companies do not understand how critical security measures are and thus do not take complete security measures. SOHO businesses, in particular, often do not even have a dedicated system administrator with sufficient skills.

System administrators are not able to keep their systems up to date and secured, since security vulnerability alerts are being issued on a weekly basis. For example, as only to the security information related to IIS, Microsoft posted as many as 25 notices on its Web page over the past one year.

While security information is released at an early stage on the Internet, other major media usually do not report it until damage becomes widely known. For example, SirCam made its first appearance in a major newspaper, the evening edition of Mainichi Daily News, on July 24, 2001, and CodeRed was first reported in Asahi Shimbun's evening paper on July 31.

Even though an increasing number of malicious program writers have been captured recently, the authorities have yet to catch up with the growth of viruses. As creating viruses is becoming easier with a variety of tools available on the Internet, complete eradication of all viruses is virtually impossible.

In addition to traditional security services for enterprises, a new service to provide mail- virus detection on ISP servers has recently been introduced as an effective means to prevent viruses. In Japan, NDS, an Okayama-based ISP company, started this service in July 2001, followed by the leading ISP Nifty in August. Meanwhile, Symantec, an anti-virus software developer, and IBM jointly developed a technology called "Digital Immune System." The system, in response to primary infection of a new virus, immediately updates the virus pattern file and anti-virus program to be distributed to every subscriber to the service. While another ongoing approach is to develop a technology to detect a new virus without its virus definition, it will take much more time to bring into actual use.

Considering that more and more computers are expected to be used in households through the widespread use of broadband connectivity and with networked home appliances, individual-level protection is critical to reduce damage attributed to viruses. To this end, further efforts to promote basic virus protection as well as to enhance fundamental anti-virus education through facilities that provide education on IT is asked for. Also

important is earlier public attention to at least highly destructive viruses via popular media such as TV and newspapers.

*Online news sites including ZDNN and Nikkei Biz, and Web sites of the Information-technology Security Center at IPA, anti-virus software developers, Computer Emergency Response Team (CERT) at Carnegie Melon University, the National Infrastructure Protection Center (NIPC) in the U.S., and so on, were referred to during the research for this report.

Explanation of terms

*1 viruses, worms, and Trojan horses

A program that does harm to a computer is generally called a virus. When narrowly defined, a virus is a program that; (1) resides in another file and becomes active when it is opened, (2) creates a copy of itself in other files or computers upon infection, and (3) shows symptoms after a certain incubation period or at a preset trigger.

Worms are different from viruses in that; (1) they are independent and do not need host files, and (2) they are enabled to search for and infect targets by themselves.

A Trojan horse, while looking like an innocuous program, carries out in the background operations that the user of the infected system does not intend.This malicious program is different from viruses and worms in that it is not always infectious. However, many of the recent malicious programs combine the characteristics of the above three, just like SirCam, which is classified as a worm as well as a Trojan horse by some organizations.

*2 DDoS (Distributed Denial of Service) attacks

In a DoS (Denial of Service) attack, a targeted Web site or network is swamped with an overwhelming amount of simultaneous accesses, so that the service it provides grinds to a halt. For a DDoS attack, a type of DoS attacks, the attacker typically takes control of a large number of third-party systems through hacking or other techniques to launch DoS attacks from multiple places.

*3 virus pattern file

This file contains a database of patterns that are specific to virus programs. Anti-virus software uses these patterns to detect viruses. As the pattern varies by virus, users are required to keep their virus pattern files up to date in order to prevent new viruses.

5

Present Status and Problems Associated with Waste Disposal Technologies Aiming at Efficient Utilization of Energy Contained in Combustible Wastes

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5.1 Introduction

The construction of a recycling-oriented society is one of the highest goals in the environment-related policy area for which a nationwide consensus has been formed.

What we have to recycle primarily in such a society are generally visible resources and wastes and, in this sense, such a recycle can be called as the "Material Recycle."

The law system to encourage the Material Recycle has been improved steadily and is beginning to produce tangible results. However, given our current technological level, it is still difficult to recycle every material for reuse. And that is where the "Thermal Recycle" in which wastes, etc., are utilized as a source of energy, comes in as a means to fill the gap and utilize what is difficult to recycle or reuse as a material.

The "Thermal Recycle" can be seen as a means to make possible effective utilization of energy that is currently unutilized and wasted. Today, among the wastes discharged from general household and industrial activities, a huge amount is just incinerated without being recycled and the thermal recycling of them, if realized, will help save resources on a rather substantial scale.

So then, we are confronted with a problem. We have not yet developed efficient and safe waste burning technologies that are basis of the Thermal Recycle.

In this paper, we will discuss the present status and problems associated with waste incineration technologies which is indispensable to the Thermal Recycle, focusing on utilization of energy recovered from wastes.

5.2 Present status of the Thermal Recycle

5.2.1 *Present status of heat recovery from wastes*

It is possible to identify the size of each category of the sources generating wastes from press releases by the former Ministry of Health and Welfare (MHW) and the white paper issued by the former Environment Agency. According to statistics released by MHW in June 2000, the amount of municipal solid wastes discharged annually from homes, etc., was 51,200,000 tons in 1997, indicating that each one of us generated about 1.1 kg of wastes everyday. Approximately 70% of these wastes was disposed of by means of direct incineration, while the rest was disposed of as bulky wastes or recycled as resources. (See Chart 1)

By far, much larger amount, however, is discharged as industrial wastes. The total amount discharged in 1997 reached approximately 415,000,000 tons, 43% of which or surprisingly about 180,000,000 tons went to direct incineration. (See Chart 2)

For instance, to examine plastics among recovered wastes, they have an energy density as large as 37 giga joules/ton. These potential sources of energy, however, are just burned in relatively simple, small or medium-scale incinerators and the huge amount of waste heat are almost in no use.

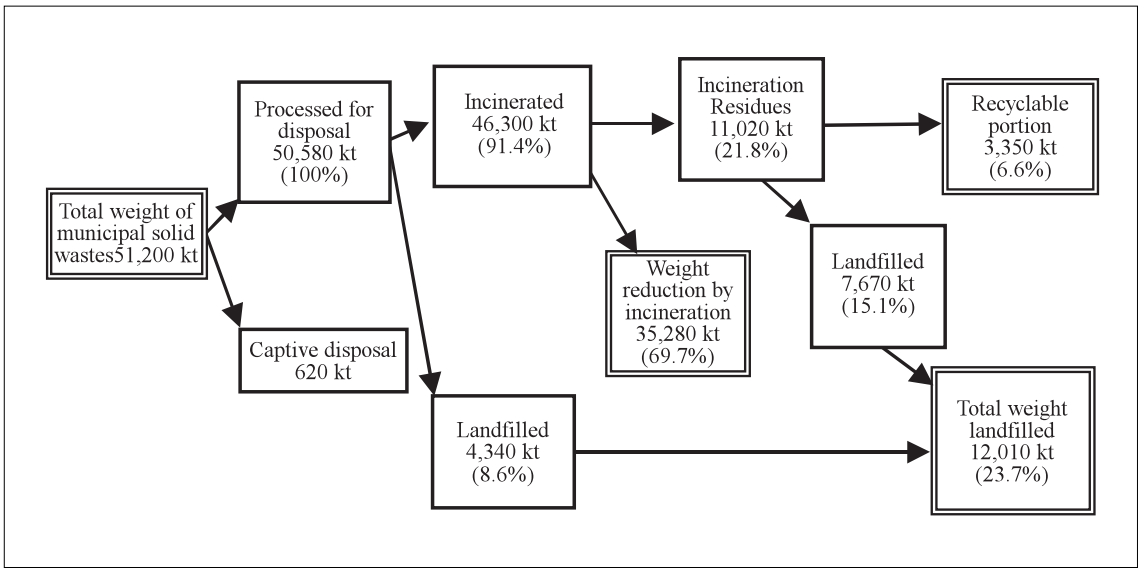
5.2.2 *Institutional aspect of the Thermal Recycle*

Today, the law system to promote the construction of a recycling-oriented society has been improved to a considerable level. In our law system, the

following four laws have been legislated as regulatory measures taking the characteristics of particular products into consideration: "Law for Promotion of Sorted Collection and Recycling of Containers and Packaging (Container and Packaging Recycle Law)," "Law for Recycling of Specified Kinds of Home Electric Appliances (Home Electric Appliance Recycle Law)," "Law for Recycling of Materials involved in Construction Work (Construction Material Recycle Law)," and "Law for the Promotion of Recycling of Recyclable Dietary Resources (Food Recycle Law)."

Among these laws, the Home Electric Appliance Recycle Law and the Construction Material Recycle Law have recognized the Thermal Recycle as one possible form of recycling, while they give priority to the Material Recycle as the most desirable form. The Home Electric Appliance

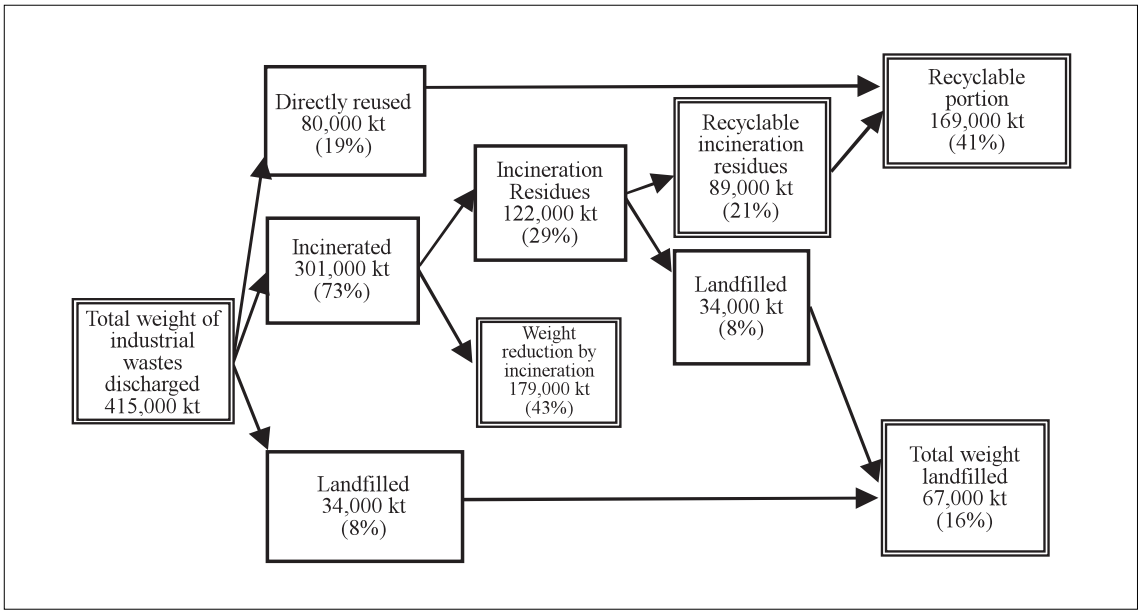
Chart 1: Disposal flow of municipal solid wastes in Japan



Source: "The status of municipal solid waste generation and disposal in FY1997" http://www1.mhlw.go.jp/houdou/1206/h0623-2_14.html MHW's data were summarized and compiled into the above chart by the Science & Technology Foresight Center

Note: Due to measurement rounding, there are cases where percentages shown do not total to 100% when added.

Chart 2: Disposal flow of industrial wastes in Japan



Source: "The status of industrial waste generation and disposal in FY1997" http://www1.mhlw.go.jp/houdou/1206/h0623-2_14.html MHW's data were summarized and compiled into the above chart by the Science & Technology Foresight Center

Note: Due to measurement rounding, there are cases where percentages shown do not total to 100% when added.

Recycle Law, however, does not specify quantitative lefel for the Thermal Recycle, which utilizes plastic parts, etc., as a fuel, while it specifies recycle-rate requirements for the Material Recycle, which recycles or reuses waste parts and materials in future products. The Construction Material Recycle Law, which will be put into effect in April 2002, adopts a principle that the Thermal Recycle should be considered for combustible wastes that are rarely reusable or technically difficult to recycle as material.

5.3 Present status of incineration technologies supporting the Thermal Recycle

5.3.1 Incineration in the form of RDF

Nearly 70% of the combustible wastes discharged from homes goes to incineration as shown in Chart 1, and its utilization as an heat resource has already been practiced in the process of volume reduction of wastes.

One embodiment is power generation from wastes, in which combustible wastes are processed into pelletized solid fuel called RDF (Refuse Derived Fuel) and burned in a fluidized bed furnace, etc. RDF, which is produced by crushing raw wastes and compacting it into pellets of about 1.5 centimeters in diameter and several centimeters long after dehydration, is lightweight and does not have any offending smell. RDF offers a number of advantages including that it can reduce the weight of raw wastes containing a lot of water and, therefore, also transportation costs, that it opens the way to a more economical disposal system through expansion of the scale to cover an extensive area, and that it will allow a large-scale furnace to operate continuously at a high temperature so that generation of dioxins can be suppressed.

On the other hand, RDF still has some problems. In the technical aspect, it requires selective removal of foreign matters such as pebbles and metals to protect crusher equipment used in the production process. In the economic aspect, 1 ton of raw wastes requires 65 liters of kerosene for processing (trial calculation by the Enterprise Agency of the Mie Prefectural Government), making RDF's production cost very expensive. In the environmental aspect, volume reduction or effective utilization of remaining ash after burning is necessary due to an increase in the ash content resulting from the addition of quick lime. It has been pointed out that solutions are needed for these problems. Thus, there are still many problems awaiting solutions before efficient Thermal Recycle is performed with RDF power generation.

5.3.2 Conventional type incineration

One of the conventional methods still employed by many incineration facilities up to today is the stoker method. In this method, wastes are placed on a grid called a stoker, conveyed slowly and burnt, while air is blown from the underneath. The efficiency of power generation from wastes is normally very low, measuring at something between 10 and 15%. The reason is because operation at a low temperature is preferred based on the following grounds and this, as a result, forces a boiler to accept low-temperature steam: (1) when the combustion gas of wastes rises to a high temperature beyond 300 ℃, hydrogen chloride gas contained in the combustion gas and alkali-metal salts having a low-melting point will make the boiler superheater steel tubes corrodible easily; and, (2) a furnace bed holding wastes for incineration tends to deteriorate more from oxidation when the combustion temperature becomes higher, and thus low temperature operation ensures longer useful life of the equipment.

For the problem of superheater tube corrosion, development of a stainless steel based new material together with some operational improvements such as the adoption of combustion at a low air-fuel ratio is believed to provide a solution. For the problem of furnace bed deterioration, several major furnace manufacturers proposed the adoption of a water cooled internal structure to avoid excessive heating of a furnace bed in addition to the improvement of the furnace bed structure itself. With these improvements, a system offering over 20% efficiency of power generation using high-temperature, high-pressure steam of 400 ℃ and 40 atmospheric pressure produced in a boiler has

been put to practical use. Furthermore, major manufactures are conducting experiments to materialize over 30% power generation efficiency by raising the temperature and pressure of steam to 500 ℃ and 50 atmospheric pressure, respectively.

5.3.3 Commercialization of an ash-melting gasification furnace

Besides its low power generation efficiency, the conventional power generation system using wastes is known for having the problem of dioxin generation due to low-temperature combustion. To overcome these problems, an ash-melting gasification furnaces were developed by about 20 major manufacturers and is beginning to be put to practical use.

The basic mechanism of an ash-melting gasification furnace is to gasify wastes through thermal decomposition at a temperature between 300 and 600 ℃ in the gasification furnace section, and then to extract molten ash (slag) and metals such as iron at over 1200 ℃ in the melting furnace section. The boiler section does not only exstracting heat but also uses it for power generation, while exhaust gases are released through a stack to the open air after removing chlorides with a gas purification system and ash with a dust collector.

Ash-melting gaasification furnaces are grouped into three types depending on their gasification furnace and melting furnace structures. They are the direct melting furnace (shaft furnace) that has a combined gasification and melting furnace, the kiln type furnace that burns wastes in the melting furnace after gasifying it in a rotating drum furnace (gasification kiln) heated to about 450 ℃, and the fluidized bed type furnace that blows air from the bottom of the gasification furnace heated to around 600 ℃ and fluidizes hot sand in the furnace to gasify wastes. Chart 3 shows a schematic flow of the process common to them together with the composition of gases.

Ash-melting gasification furnaces depicted here were developed under MHW's basic policy to concentrate waste disposal to large-scale furnaces with a view to reducing the concentration of dioxin emission, as well as being designed to handle several hundred tons of wastes a day. They draw high expectation as promising means for materializing the Thermal Recycle.

5.3.4 New trend of ash-melting gasification furnace technologies

While a large-scale ash-melting gasification furnace is a promising technology, it is not a suitable choice for an enterprise or local governments whose volume of waste discharge is several tons to several ten tons a day. As one example of technological developments addressing such smaller needs, a new incineration technology employing a small-scale ash-melting gasification

Chart 3: Schematic system of an ash-melting gasification furnace and flow of gas components

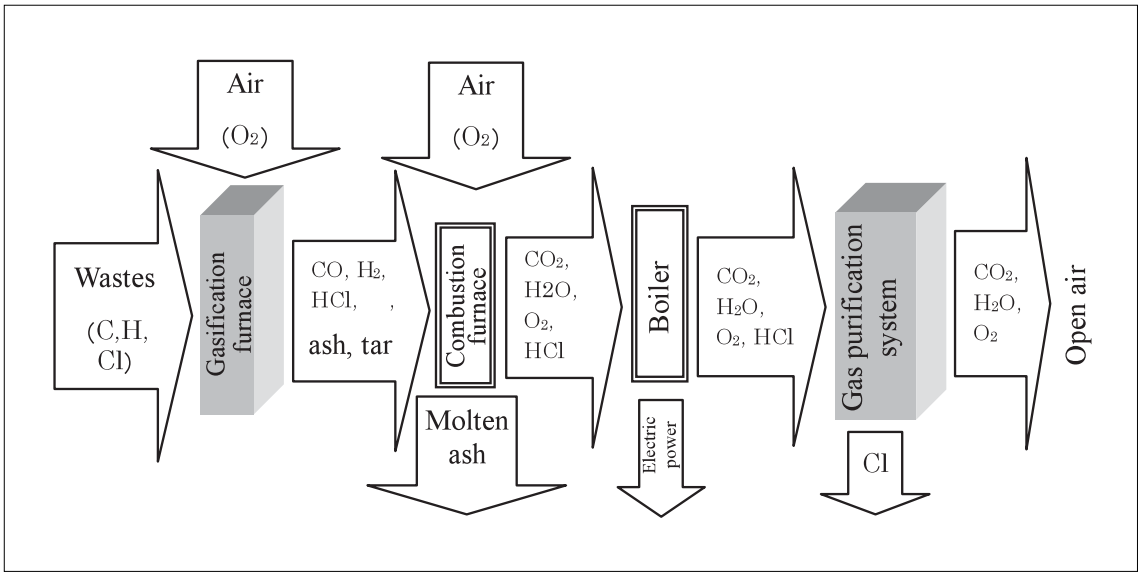


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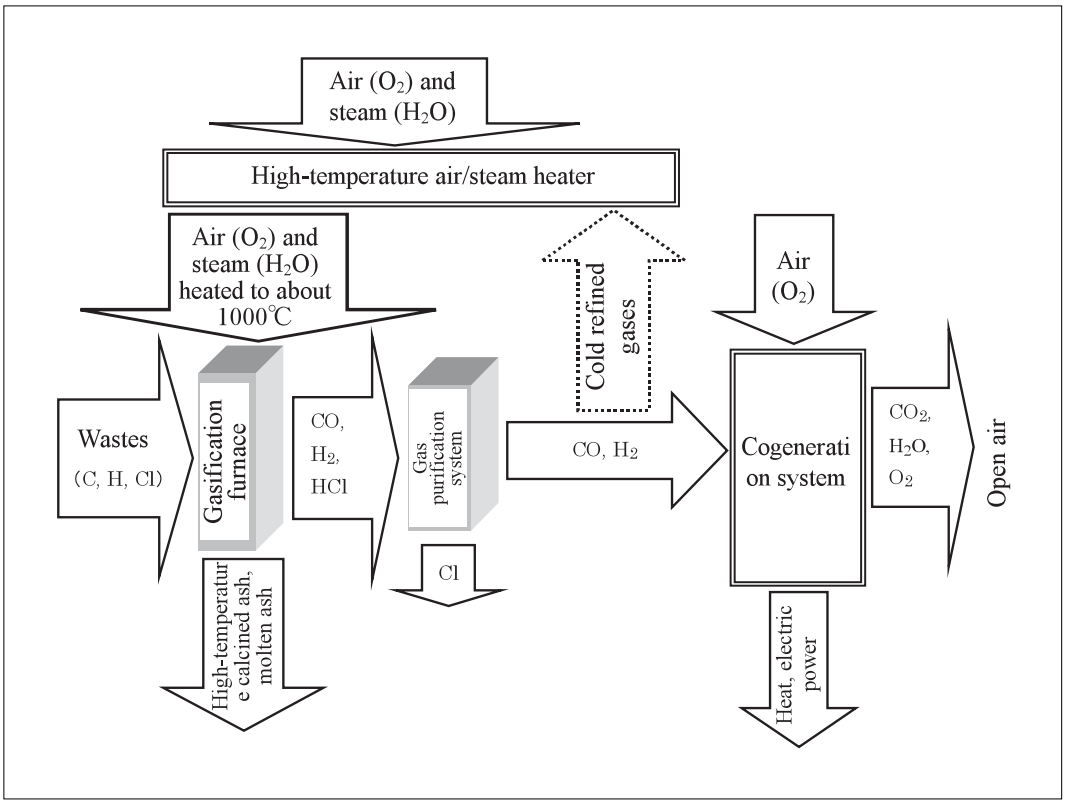
Chart 4: Schematic system of power generation using a new ash-melting gasification technology and flow of gas components



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system has been developed at Tokyo Institute of Technology under the sponsorship of the Japan Science and Technology Corporation as a part of the CREST (Core Research for Evolutional Science and Technology) Project.

While the process of this new system is depicted in Chart 4, its major difference from a large-scale ash-melting gasification furnace lies in that high-temperature fuel gases extracted from the gasification furnace are, after they are cooled and purified, introduced to a cogeneration system (an engine generator and a boiler) to convert them into electric power and steam.

Another characteristic point of the new system is that it can minimize dioxin generation because it has a high-temperature reducing atmosphere created with high-temperature air/steam of about 1000 ℃ introduced to a gasification furnace, with fuel gases removed of chlorides burned in a cogeneration system as depicted in Chart 4.

The most advantageous point of this system is that it can utilize exhaust heat produced upon combustion at the site of waste generation, as the compactness of the system allows its installation near the site of waste generation. When these advantageous features of the system are fully utilized, it is expected to make a positive contribution to the advancement of waste heat utilization as well as power generation. If it is installed in each factory or building, it is expected to not only establish a positive waste disposal model as a vein system for a recycle-oriented society but also, at the same time, to open the way to utilize as distributed energy sources materializing the Thermal Recycle.

5.4 Future R&D Problems

5.4.1 High-efficiency power generation technology

Local governments, which are beneficiaries of the large-scale ash-melting gasification furnace technologies aspiring for high-efficiency power generation, hold high expectation on it. Furthermore, medium to small-scale entities discharging wastes are increasing expectation on the new ash-melting gasification furnace technologies, as it may allow them to secure waste disposal means and energy sources at the same time.

While high expectation is placed on these technologies, their commercial viability as a system, including power generation efficiency, has yet to be assessed to determine whether they are feasible technologies capable of sustaining the Thermal Recycle. In the meantime, the new ash-melting gasification furnace technologies still have many problems requiring solutions including gas production from wastes and operation of a generator with low-calorie gases. While small to medium-scale factories and small-scale local governments need to dispose wastes whose amount is several tons to several ten tons a day, a system may be required to operate intermittently, such as on each alternate day, and the reliability of a system in such an intermittent operation mode will also be required.

5.4.2 Peripheral technologies

Waste incinerators such as represented by ash-melting gasification furnaces need to incorporate a system that causes little environmental loads, while they are capable of sustaining the Thermal Recycle. In other words, it is essential to keep close watch on substances produced in the incineration process such as NOx and dioxins.

In addressing environmental problems, establishment of measuring technology is the first thing to be achieved. With regard to dioxins generated in the process of waste incineration, technology making direct and real-time measurement possible has yet to be developed. For direct measurement of dioxin concentration, a laser method is regarded as the most promising option and some private enterprises are exploiting this possibility. However, examination and classification of a huge volume of optical molecular data will be necessary before estimation of a concentration from measurement results becomes possible.

Besides, there are a number of problems requiring solutions, including technology to remove dioxins remaining within incinerators.

5.5 Conclusion

To promote the construction of a recycling society, it is necessary to establish the Thermal Recycle, to say nothing of the promotion of the Material Recycle, for the utilization of wastes not covered by the latter. To further promotion of the Thermal Recycle, establishment of technology that provides a basis together with institutional development is a pressing necessity.

Key technologies to sustain the Thermal Recycle including an ash-melting gasification furnace are expected to play important roles in achieving energy saving through utilization of waste heat, and we need to steadily advance research and development to materialize effective utilization of waste heat while minimizing impacts on the environment.

6

A Trend of Hazardous Substance Detection in the Environment

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6.1 Introduction

Environmental pollution manifesting in the form of serious diseases such as the Minamata disease in the 1950s through the 1970s was caused by limited kinds of pollutants including locally accumulated organic mercury. Today, we are facing threats from environmental pollution caused by a variety of hazardous substances that are present in a minimal-quantity but over a vast extent, (for example, endocrine disrupters including nonylphenol and dioxins).

Today, physical and chemical measurement techniques are employed as the mainstream of measuring technology applied to such trace hazardous substances, but this does not necessarily mean that they are satisfactory as environmental measurement techniques. In recent years, environmental measurement techniques using biological means have drawn greater attention as a means to supplement the former, and various R&D efforts have been started.

In this article, the recent trend of measuring technology for trace hazardous substances using physical, chemical and biological techniques will be reviewed.

6.2 Physical and chemical techniques

Environmental measurement using physical and chemical techniques includes gas chromatography /mass spectrograph (GC/MS) measurement and high-performance liquid chromatography/mass spectrograph (HPLC/MS) measurement. The problems currently experienced in conducting environmental measurement with GC/MS are depicted below.

6.2.1 GC/MS

GC/MS has become one of the most powerful tools for the analysis of complex organic and biochemical mixtures. GC/MS consists of two components; (i) gas chromatography (GC), which single out chemical substances and (ii) mass spectrometry (MS), which quantitatively identifies each chemical substance.

By the way, what is the required level of accuracy for GC/MS in measuring trace hazardous substances? For dioxins, as an example, which are known for their high toxicity levels, the Japan Industrial Standards (JIS) adopted the lower limit of detection in 1999 as follows.

According to JIS, the lower limit of detection is 0.1 pg (pico gram = one trillionth of a gram) for the tetra-chlorinated and the penta-chlorinated, 0.2 pg for the hexa-chlorinated and the hepta-chlorinated, 0.5 pg for the octa-chlorinated and 0.2 pg for coplanar PCB [1]. Therefore GC/MS must have a very high accuracy to detect very small amounts of hazardous chemicals.

Incidentally, the presence of these substances in the environment is normally expressed by the concentration level (expressed by the mass of such a substance contained in 1g of water. Concentration of chemical substances in the environment is expressed in terms of ppm (parts per million), ppb (part per billion) and ppt (parts per trillion).

6.2.2 Problems of measurement with GC/MS

To measure traces of hazardous substances by GC/MS, sample pretreatment such as singling out an object substance from samples (extraction, refining, etc.) is necessary, making the process more complicated, expensive and time consuming, than that of normal substances.

A measurement of dioxins requires an accuracy

level in the order of ppt. An expensive high-accuracy equipment (which costs 100 million Yen or so) and as well as time-consuming pretreatment are necessary. Even when a measurement is requested from an outside specialist organ, it costs 200,000 Yen and takes 1 to 2 weeks per sample. Although on-the-spot measurement is desirable to prevent contamination at places other than sampling by object substances of measurement, realization of on-the-spot measurement is difficult due to the involvement of large-scale equipment.
Due to these problems, it is also difficult to conduct measurement for a long period and frequently in a factory or at a number of points scattered over an extensive area.

6.3 Biological techniques

In recent years, environmental detection using biological means has begun to draw our attention. These techniques can be classified as

1) techniques using individual organisms;
2) techniques using organic substances;
3) techniques using gene recombined organisms.

6.3.1 Techniques using individual organisms

In this technique, an/a group of animals or plants is/are used. The toxicity degree of the applied chemical substances can be measured from the changes of the animal(s) or plant(s).
For example, groups of mice or Japanese killifish (medaka) were fed with different concentration levels of endocrine. An individual organ, such as a spermary or ovary, of the mice was investigated. This can bee used to explain a breeding ability of mice in the environment contaminated with endocrine for several months.
In terms of quantitative measurement, such techniques have limitations in providing accurate information. Moreover, time duration ranging from several weeks to several years is needed in some cases. However, these techniques offer a relatively easier means to investigate the influence of chemical substances on living bodies, which cannot be performed by physical or chemical techniques. In this sense, such biological techniques offer means suitable for determination of toxicity for environmental measurement.

6.3.2 Techniques using organic substances

Here what we call organic substances are receptors and antibodies produced in living bodies. These techniques employ a system utilizing such organic substances, or a biosensor, for measurement.
Biosensors using receptors or antibodies are introduced below.

(1) Biosensors utilizing receptors

Dr. Masaharu Murata of the Engineering Study Course of the Post Graduate School of Kyushu University has developed a new small biosensor that can response to endocrine disrupters within 1 minute.
This sensor has female hormone (estrogen) receptors held on an electrode. When the endocrine disrupter, which is similar to the female hormone, is present. The receptors change their three-dimensional structure significantly. This leads to a change in the conductance of the receptors, allowing us to determine the concentration of the endocrine disrupter accurately. Using this principle, any endocrine disrupters can be measured, if the appropriate receptors are applied.

(2) Biosensor utilizing antigen-antibody reaction

Dr. Naoya Omura of the Abiko Central Research Institute of the Electric Power Industry has developed a simple biosensor utilizing antigen-antibody reaction that can measure several kinds of female hormones, PCB, etc., present in an extremely small quantity with quite high sensitivity.
Object antigens for measurement are adsorbed on the surfaces of plastic balls of a diameter measuring around 100μm and held in a measuring device. Then sample fluid mixed with antibodies marked with fluorescent coloring matter and a sample is flown through the measuring device. If antigens are not included in the sample fluid, all antibodies marked with fluorescent coloring matter are coupled with antigens on the plastic balls and captured. So, the plastic balls will emit strong light, when light is irradiated onto them.

On the other hand, if the sample fluid contains antigens, antibodies marked with fluorescent coloring matter are coupled with antigens present in the sample fluid. In this situation, less antibodies are coupled with antigens on the plastic balls, making the intensity of light weaker. From the difference of light intensity measured between when antigens are present in sample fluid and when they are not, the quantity of antigens that are present in the sample fluid can be measured. In the case of estradiol (E2), a kind of female hormone, the sensor can detect it at a concentration level as low as 1 ppt, within 10 minutes.

The Institute is planning to develop a portable type instrument with a size of 30 cm × 30 cm × 30 cm within this year.

6.3.3 Techniques using gene recombinant organisms

These techniques use gene recombinant organisms to show the influence of hazardous substances. These organisms are called reporters. The reporter organisms include enzymes that change color or emit light when exposed to specific hormones or substances.

The following is an example of a reporter plant study.

Associate professor Kenichi Yamazaki of the Graduate School of Environmental Earth Science of Hokkaido University and his colleagues are creating a gene-recombinant plant that can detect endocrine disrupters in water or soil.

This plant has the genes representing a female hormone receptor and a gene representing a fluorescent protein substituting the specific protein manifestation of which is induced by the said female hormone through gene manipulation. As a result, when the plant takes in an endocrine disrupter that activates the female hormone, the fluorescent protein is produced within the plant body.

Through measurement of the intensity of green fluorescence emission during the irradiation of blue light onto the plant, quantitative measurement of the fluorescent protein in the plant body can be made relatively easily. When the quantity of an endocrine disrupter increases, the quantity of fluorescent protein also increases, thus, in their opinion, making estimation of the quantity possible through measurement of the intensity of fluorescence emission from the plant body.

6.4 Direction of environmental measurement

The characteristics of physical and chemical techniques and the three types of biological techniques are compared in Chart 1. The quantity acting on organisms means the quantity of the substance coupled with specific parts (such as receptors and antibodies) of organisms. This parameter is essential since the hazardous substances present in the environment do not show any influence unless they really act on the organisms. Time, cost, and restriction of the place for measurement are considered as the ease and convenience of measurement.

The physical and chemical techniques can

Chart 1: Comparison of environmental measurement techniques

Environmental measurement techniques	Measurement of the quantity of a substance present in the environment	Measurement of the quantity acting on organisms	Ease and convenience of measurement
Physical and chemical techniques	◎ (possible up to ppq)	×	△
Techniques using individual organisms	△	×	△
Techniques using organic substances	○ (possible up to ppt)	◎	◎
Techniques using gene recombinant organisms	△	○	○

◎: Most suitable ○: Suitable △: Suitable to a limited extent ×: Not suitable

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accurately measure the amount of hazardous substances present in the sample. In December 2000, one Japanese electronic instrument maker developed the equipment that can measure dioxins as low as the order of ppq (parts per quadrillion).

However, these techniques are not convenient as it is not portable and a sample pretreatment is needed. Moreover, the influence of hazardous substance on the organisms cannot be determined. Therefore the instrument which are smaller in size lower in cost and allows simplified pretreatment are being developed.

Techniques using individual organisms offer an approximate measurement. The influence of hazardous substances can be observed. They, however, lack of the ease and convenience, as they require long-time observation, e.g. breeding, under consistent conditions. At present, the available techniques allow the measurement of a single substance at a time. Efforts are being made to establish a technique able to measure more than one substance at a time.

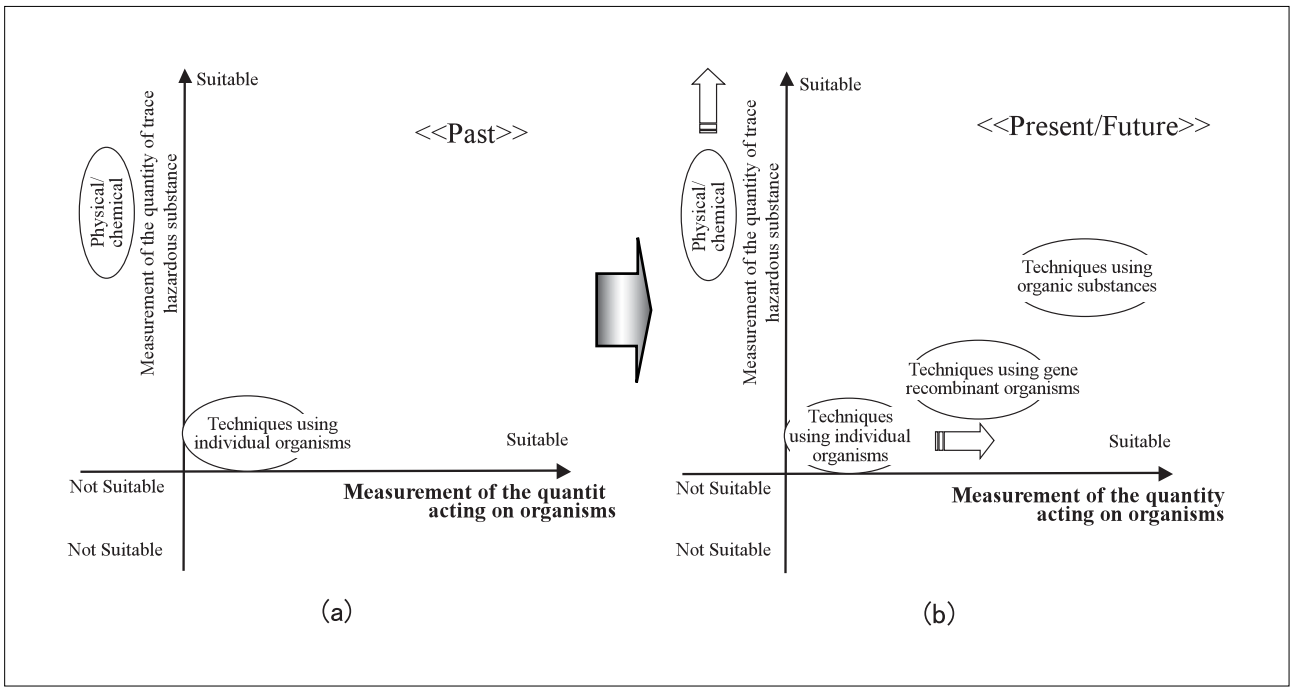
Techniques using organic substances employ a compact sensor for measurement. They offer highly accurate measurement (up to the order of ppt), short time consuming, portability and low cost. On condition that the testing samples are limited and sensitive.Therefore care must be taken during the measurement. Otherwise the measurement result can be estimated in error.

Techniques using gene recombinant organisms are simple and easy. The reporter plants are grown using testing water or soil containing hazardous substance(s). However, organic substances and genes used as samples in this technique are very limited. If these techniques are developed, long-term and fixed-point observation will be possible.

The four environmental measurement techniques are shown in Chart 2, according to their accuracy levels.

As indicated in Chart 2(a), physical and chemical techniques assumed the responsibility of measurement of the mass of a substance and techniques using individual organisms, the quantity acting on organisms at a measurement level indicating an approximate yardstick of its influence in past environmental measurement practices. This basic structure is beginning to change with the enhancement of biological techniques and is now heading for the structure shown in Chart 2(b) as the current and future trend. In other words, the trend toward increasingly enhanced measurement of the quantity acting on organisms can be recognized from these figures. At the same time, the accuracy of physical and chemical techniques is being improved and developed toward the direction

Chart 2: Classification of environmental measurement/assessment techniques (objects of measurement/assessment)



shown by an arrow in the Chart 2(b) is also observed for techniques using individual organisms.

6.5 Conclusion

Biological techniques using organic substances and gene recombinant organisms are only in their infant R&D stages. To establish these techniques and enrich the available options for environmental measurement, efforts should be made in the following areas.

Normally, creation of antibodies takes several months and it is difficult to create antibodies for a substance that has toxicity against an animal body. Accordingly, it is desired to create a system that renders support in distributing or creating antibodies and offers a basis to R&D of organic substances usable for a sensor such as antibodies.

It is also considered to be necessary to promote follow-up tests of newly developed techniques for their verification, and give an official certification when such technique is found appropriate as a measuring method to help such technology spread widely.

The law of "Pollutant Release and Transfer Register (PRTR)" was enforced in March last year, and management of chemical substances was enhanced to prevent problems harmful to environmental preservation before they actually occur. The said law also states clearly that it is the government's responsibility to promote researches in a comprehensive manner to obtain scientific knowledge on the influence of specified chemical substances affecting human health, animals and plants.

In view of such legislation, the ability to perform monitoring of chemical substances including hazardous substances mentioned in this report for their movement in the environment and the assessment of their influence on human bodies and the ecosystem in a more detailed and simpler manner has become necessary.

Therefore, it is desirable to advance R&D of biological environmental measurement technologies to obtain diverse means for measurement, while continuing to improve the physical and chemical techniques, so that they may offer appropriate combinations to realize effective environmental measurement.

Notes:

[1] Taken from JIS K0311, "Method of measurement of dioxins and coplanar PCB in exhaust gases," and JIS K0312, "Method of measurement of dioxins and coplanar PCB in industrial water and plant wastewater."

7

New Superconducting Material MgB_2 and the Trends in Research and Development

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7.1 Introduction

The discovery of the superconductivity of magnesium diboride (MgB_2) by Professor Jun Akimitsu's group of Aoyama Gakuin University was announced for the first time to the participates at a study meeting in Sendai (January 10, 2001), and the news spread all over the world before the report appeared in the scientific magazine Nature (March 1, 2001). Since then, intensive research has been made worldwide and fundamental data are being published in succession.

The superconducting critical temperature of MgB_2 is 39K, which is higher than the temperature range of 20 to 30K that has been considered to be the limit for metallic superconductors. Therefore, it is very likely that it can be used at temperatures relatively easily attainable using refrigerators (about 20K)*1, and its practicality is attracting researchers' attention.

This paper outlines the past research and development in superconductivity, and then reviews, relating to MgB_2, the characteristics and possibilities of application that have been elucidated, and the situation of domestic and overseas research and development.

7.2 Trends in past research and development on superconductivity

7.2.1 History of the discoveries of superconducting materials

In 1911, the physicist, Kamerlingh Onnes, discovered superconductivity (mercury, critical temperature 4K) for the first time. Since then, critical temperatures of metallic superconductors (generally having low critical temperatures and referred to as low temperature superconductor LTS) have been raised over many years and reached 23K (Nb_3Ge) in the 1970s. NbTi used for the magnetic resonance imaging apparatus (MRI) is one of the LTSs.

On the other hand, the high temperature super conductor (HTS) was discovered by Bednorz and Muller of the IBM Zurich Laboratory in 1986, and the critical temperature was raised up to 130K (mercury compounds) within several years. No material having a critical temperature higher than

Chart 1: Superconducting materials that have been discovered recently

1980	D. Jerome and co-workers of University Paris-Sud found the superconducting organic material, $(TMTSF)_2PF_6$
1986	Bednorz and Muller of the IBM Zurich Laboratory found an oxide high temperature superconductor.
1991	A. F. Hebard and co-workers in University of Florida found the superconductivity of a fullerene (C_{60}). (C_{60} doped with potassium)
November 2000	B. Batlogg's group of Bell Laboratories announced that they had discovered the superconductivity of C_{60} having a field-effect transistor (FET) structure (critical temperature: 52K). At the same time, it was reported that polycycle aromatic hydrocarbons such as anthracene, pentacene, and tetracene as well as polymer, polythiophene show superconducting transition.
March 2001	J. Akimitsu's group of Aoyama Gakuin University officially announced that MgB_2 undergoes transition to superconducting state at 39K.
April 2001	S. Uji and colleagues of the National Institute for Materials Science reported that λ-$(BETS)_2FeCl_4$ showed the magnetic-field-induced superconductivity in the magnetic field of 18T or higher.

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that has been found since then. High temperature superconductors that are being developed aiming at practical use at the liquid nitrogen temperature of 77K are mainly the bismuth compounds (critical temperature: 110K) and the yttrium compounds (critical temperature: 92K).

Search for the superconductivity of organic materials began on a full-scale in the 1970s, and $(TMTSF)_2PF_6$ was the first organic material to be found as a superconductor. Since then, many superconducting organic materials have been synthesized and the highest critical temperature that has been attained so far is 12K. Then, the superconductivity of fullerenes was discovered in 1991, and the present highest critical temperature is 33K of $PbCs_2C_{60}$. Recently, the C_{60} having a field-effect transistor structure has become the focus of attention due to its superconductivity transition at the critical temperature of 52K.

7.2.2 Research on applications

Research works on applications of LTS and HTS materials are being conducted mainly for the following uses.

(1) Electric power system

For energy saving and stabilization of electrical power systems, electrical power cables, transformers, superconducting magnetic energy storage system(s) (SMES), and superconducting bearings for the flywheel electrical power storage system are being developed using superconducting materials.

(2) Superconducting magnet for MRI and NMR (nuclear magnetic resonance)

Products using LTS wires made of NbTi and Nb_3Sn are on the market, and LTS and HTS wires required for superconducting magnets used for NMR under 20T or higher are being developed.

(3) Information device and filter

The single flux quantum (SFQ) device, which is expected to contribute to the information technology devices of the next generation that realize fast operation, and superconducting receiving filters used for receiver front ends for base stations of portable telephone systems are being developed.

(4) Sensor

It is being studied to apply SQUID*2 using LTS to high-sensitivity magnetic flux meters, high-resolution X-ray analyzers, and high-sensitivity mass spectrometers used for LSI inspection, etc.

(5) Magnetic separation

Magnetic separation and purification equipment used for water purification and removal of environmental hormones are being developed making use of strong magnets of HTS bulk material and superconducting magnets.

Hopes are set on HTS materials for their high performance and economical merits. As a strategy taken in the actual research projects on the application of HTS materials, however, equipment is first developed using LTS materials available at the time of development and then the LTS materials are replaced by HTS materials when they become available.

As for the developments of superconductivity technologies by private companies, venture businesses play an important role in the U.S., and large companies are at the center of development in Japan. In Europe, both large companies and venture businesses are involved.

7.2.3 Trends in research and development in Japan

At universities, search for new superconducting materials and development of devices, wire making technology, and equipment related to electrical power systems are being conducted. At the National Research Institute for Materials (now reorganized as the National Institute for Materials Science), development of Nb_3Sn wires used for generating a high magnetic field of 10T or more and search for bismuth compound HTS are being carried out, and the HTS wire technology and the first 900MHz-MNR in the world are aimed at in a multi-core project sponsored by the Ministry of Education, Culture, Sports, Science and Technology (former Science and Technology Agency).

At the International Superconductivity Technology Center (ISTEC), jointly established by the Ministry of Economy, Trade, and Industry (former Ministry of International Trade and Industry) and private companies, research and development on basic physical properties, electrical power systems,

information devices, and bulk materials are being carried out.

For these 10 years, superconducting wires have been developed under the leadership of electric cable manufacturers such as Furukawa Electric Co. and Kobe Steel. Recently, however, tests conducted on 100m long HTS power transmission cables have been started jointly by the Central Research Institute of Electric Power Industry, Tokyo Electric Power Co., and Sumitomo Electric Industries.

Among the progressing developments of superconductivity devices carried out mainly by electrical and communication companies are: HTS Josephson device by Toshiba Corp., HTS magnetic sensor by Sanyo Denki Co. and Sharp Corp., AD converter using a single flux quantum (SFQ) device operating at 100GHz by Hitachi.

The present large market for superconducting products is that of superconducting magnets used for NMR and MRI. LTS materials such as NbTi and Nb_3Sn are used for this application, and the market value is estimated at ¥10 billion per year*3. Although the quality of LTS wires produced in Japan is at the top level of the world, price competition is very keen.

7.3 Superconductivity of magnesium diboride (MgB_2)

The news of the super conductivity of MgB_2 attracted the attention not only of superconductivity researchers but also of the mass media. The critical temperature of MgB_2 is not so high as those of copper oxide superconductors referred to as yttrium compounds and bismuth compounds, which are 90K to 110K. However, it is worthy of note that a superconducting material, which has a relatively high critical temperature, has been found in addition to copper oxides.

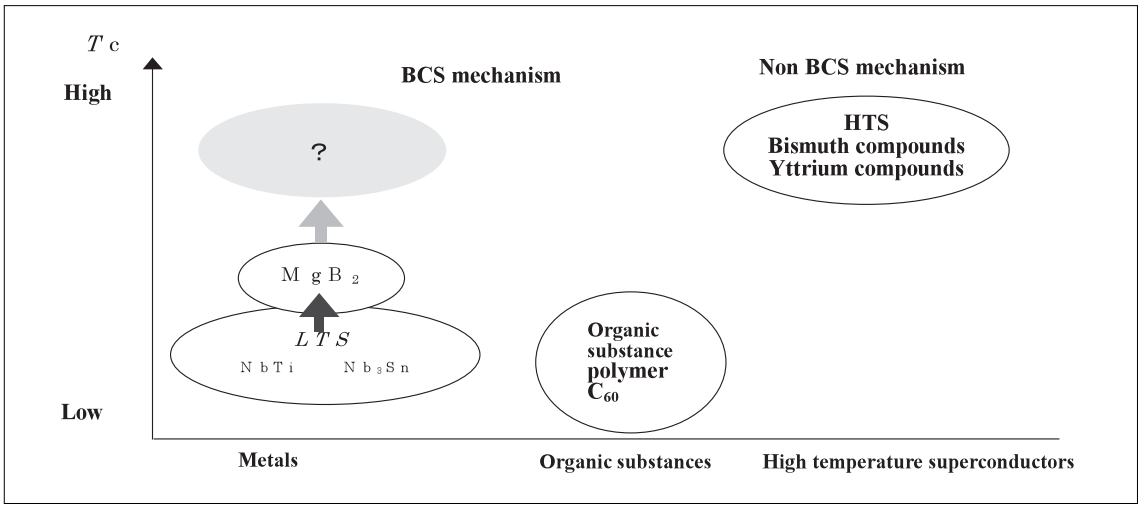
7.3.1 Basic physical properties of MgB_2 and mechanism of superconductivity

Research to clarify why MgB_2 has relatively high critical temperature is being conducted intensively worldwide. It has important meaning to consider whether similar materials having higher critical temperatures exist.

MgB_2 was first called a "metallic superconductor" because its superconductivity was attributed to the BCS mechanism, which is brought about by the interaction between the lattice vibration and electrons in the same way as metallic superconductors (LTSs), such as NbTi that has been put to practical use. For the BCS mechanism, the upper limit of the critical temperature has been considered to be 20 to 30K. It is now the focus of discussion, therefore, whether the superconductivity of MgB_2 is on the extension of the BCS mechanism or attributed to the magnetic interaction mechanism used for the explanation of HTS, or it is attributed to a new mechanism.

If the BCS mechanism is assumed, the critical temperature is considered to decrease as the result of the decrease in the vibration energy of lattice when the ^{10}B is replaced by the isotope of

Chart 2: Position of MgB_2



Prepared by the Science and Technology Foresight Center

Chart 3: Applications of superconductivity and materials used

Applications of superconductivity	Materials (use temperature)		
Power cable		HTS (77K)	
SMES	LTS (4K)	HTS (77K)	MgB_2 (20K)
Magnet for MRI	LTS (4K)		MgB_2 (20K)
High field magnet for NMR	LTS (4K or lower)	HTS (4Kor lower)	
Magnet for accelerator and nuclear fusion	LTS (4K)		MgB_2 (4K)
Linear motor car		HTS (77K or lower)	MgB_2 (20K)
Information technology device	LTS (4K)		MgB_2 (20K)
Sensor	LTS (4K)		MgB_2 (20K)
Bulk material (magnet)		HTS (77K)	

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^{11}B. Experimental results have shown that the critical temperature decreases by about 1K, which is half the expected value. Taking some other experimental results into consideration, many researchers so far consider that the superconductivity of MgB_2 is attributed to the BCS mechanism.

7.3.2 Possibilities of applications

Chart 3 summarizes the applications of superconductivity that already exist or are under development and materials used for the applications. Possible applications for MgB_2 are also listed. It is shown in the chart that MgB_2 has possibilities for application in a wide range of fields. The reasons why MgB_2 is the focus of attention are: i) it may be possible to use at the temperature of 20K, which is attainable by refrigerators; ii) production cost is significantly low compared to HTS wires that require silver sheaths to compensate for the brittleness and to align the direction of HTS crystals; and, iii) wires with high strength are expected. Due to these favorable characteristics, applications to SMES, to which a large stress is applied, accelerators, and magnets used for nuclear fusion are expected.

Important characteristics required in the applications are: critical temperature (T_C); critical magnetic field (B_{C2}); and, critical current density (J_C). If the value of J_C reaches 100kA/cm^2 in a magnetic field, it can be used as a material for electromagnets.

In July of this year, the National Institute for Materials Science announced that they had developed superconducting wires. According to the report, the wires were formed after filling a stainless steel tube with MgB_2 powder, and the value of J_C in a magnetic field (1T) was about 450kA/cm^2 at 4K and about 100kA /cm^2 at 20K without giving heat treatment. Since B_{C2} and J_C are improved by the method of fabrication and the addition of trace elements, the properties of MgB_2 are expected to be improved.

7.4 Trends in research on MgB_2 in Japan and overseas

Immediately after the discovery of the superconductivity of MgB_2 was announced at a meeting, many papers on the superconductivity of MgB_2 began to be published by registering to the print servers*4 of Los Alamos National Laboratory, Iowa State University of the U.S., and Aoyama Gakuin University. The number of papers published only through the server at Iowa State University has been confirmed as 202 by the end of May. Among theses papers, the number of those sent from Japan accounts for 10% to 20%, which is low compared to the situation after the oxide superconductivity was found in 1986.

7.4.1 Research and development in Japan

(1) Research on superconductivity characteristics

Search for superconducting materials mainly by adding third elements to MgB_2 and by studying related borides and boron carbides, and studies on the superconductivity characteristics are being conducted by many universities and the National Institute for Material Science.

(2) Research and development on wire production

The National Institute for Material Science is conducting research on wire production. Although Japanese wire producers are conducting research on wire production technology, they are rather conservative about the actual use because MgB_2 can not be used by cooling with liquid nitrogen and the characteristics (J_C and B_{C2}) are somewhat inferior to those of LTS and HTS*5.

(3) Research on superconducting devices

NEC has started to develop single flux quantum devices (SFQ) using MgB_2. The reason is that MgB_2 is favorable in operation cost because it can be used at higher temperatures compared to the SFQ devices that use LST niobium.

Since the superconductivity characteristics are better than those of HTS, the performance is expected to be improved, and, in addition, the quality of thin films will be easily improved due to its simple crystal structure.

7.4.2 Overseas research and development

(1) Research on superconductivity characteristics

Studies on superconductivity characteristics, wire production, and production of thin films are being made in earnest.

High-quality thin films and improvement of superconductivity characteristics by the addition of oxygen have been reported by Pohang University of Korea and Wisconsin University of the U.S., respectively. Papers on basic studies including superconductivity characteristics have been published mainly from universities in the U.S. and Europe, and some from Korea, China, etc.

(2) Research and development on wire production

Noteworthy results relating to the characteristics of wire have been reported by Ames Laboratory, Agere Systems*6 of Lucent Technologies, and Imperial College of U.K. in Europe. U.S. wire producers have started to develop the technology to produce wires of borides for MRI and SMES, considering the possibility of new superconducting borides that surpass MgB_2 in performance, but they are still taking a prudent attitude about commercialization. The technologies to produce wire including the one that has been developed for the production of brittle oxides are considered to be possibly applicable to boride materials*5.

(3) Research on superconducting devices

Research and development on SQUID and Josephson devices using MgB_2 are being conducted in the Netherlands and the U.S. Particularly, Twente University of the Netherlands confirmed the action of SQUID using the weak linkage of nano-structure (70nm × 150nm × 150nm), which shows the possibility of high integration.

7.5 Conclusion

The discovery of the superconductivity of MgB_2, having a high critical temperature for a metallic superconductor, was very important also from the viewpoint of basic science. Because MgB_2 has a simple crystal structure, fabrication is easy and it has strong possibilities for practical applications. In the future, compounds consisting of light elements will be one of the fields to which priority should be given. Clarification of the mechanism of the superconductivity of MgB_2 will bring about ways to discover new materials that have still higher critical temperatures and enables to promote the search and application studies more strategically.

The study of MgB_2 was started by Japanese researchers and provides many possibilities for the future as described above. Therefore, we, Japanese researchers, should place more emphasis on comprehensive technical development ranging from the search for new materials to application technologies such as wire and thin film production.

Explanation of terms and reference

*1 In order to maintain a stable superconducting state when a magnetic field or current is applied, it is necessary to lower the cooling temperature than the critical temperature according to the magnitude of the current or magnetic field. Therefore, superconducting magnets must be used at a temperature lower than the critical temperature of the material

being used.

*2 SQUID
Stands for superconducting quantum interference device. Very weak magnetic fields can be measured using this device.

*3 "Development of NMR/MRI Technologies", Forum of Superconductivity Science and Technology, March 2001.

*4 Preprint server
Normally, research papers undergo submission, review, acceptance, printing, and delivery; it was very rare for them to be opened to the public before acceptance. Recently, however, many papers are opened to the public on the Internet before they are reviewed and accepted. Researchers who want to get a head start in their research positively register their papers in computers that provide registering and publishing services called "preprint server". The papers can be retained on the servers during and after the publishing and offered for public inspection.

*5 SUPERCOM, Vol. 10, No. 2 (2001) in Japanese.

*6 Agere Systems
Former microelectronics division of Lucent Technologies, and now a separate subsidiary company.

8

Trends in the Development of Carbon Nanotube Production Technology

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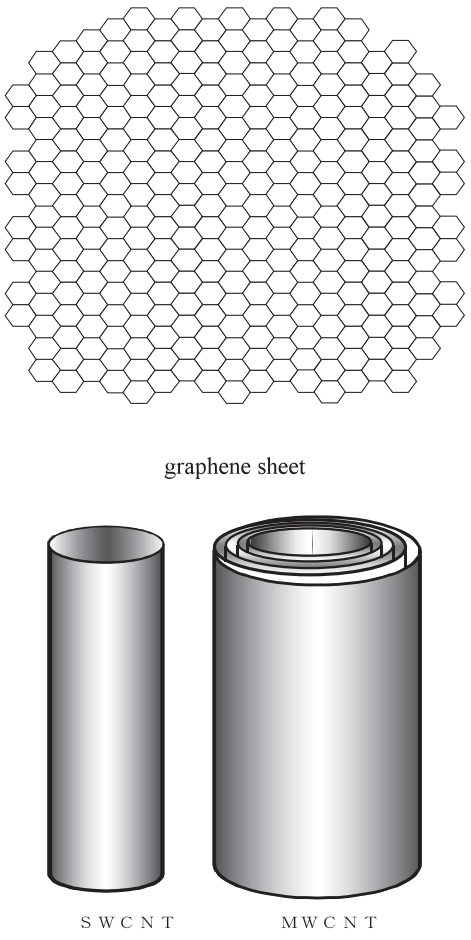
8.1 Introduction

The carbon nanotube (CNT) is a cylindrical material formed by rolling up a sheet of graphite monolayer, made up of a series of six-membered carbon rings linked together (graphene sheet), having a diameter between about 1 nm and several tens nm and a length of about 1 μm. There are two kinds of CNTs: the single-walled CNT (SWCNT) consisting of one layer of carbon atoms; and, the multi-walled CNT (MWCNT) made up of layers of concentric hollow cylinders (see Chart 1). The MWCNT was the first CNT found by Iijima of NEC in 1991, and then the SWCNT was simultaneously reported on by the NEC group and IBM group in 1993.

Recently, it has been made clear that CNTs have various unique characteristics. Among them are: i) shape (diameter at the tip is small and the aspect ratio is large); ii) electronic properties (sometimes metallic and sometimes semiconducting depending on the way the graphene sheet is rolled up and the tube diameter, resonance tunnel effect, transistor characteristics by the electric field effect, etc.); iii) adsorption characteristic; and, iv) excellent mechanical properties. Making use of these characteristics, many possibilities for application are expected. In this paper, recent trends in developing production technology for CNT, which is the key to putting this excellent material to practical use, are mainly explained.

Chart 1: Schematic diagrams of graphene sheet, SWCNT, and MWCNT.



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8.2 Expected applications for CNT, and the necessity of the development of production technology

8.2.1 Expected applications for CNT

Reflecting the progress of application development for CNTs, the number of patent applications has been drastically increasing recently. Chart 2 shows the change in the number of published patent applications in Japan by years, which shows that many ideas have been proposed

relating to the application of CNTs. Chart 3 shows examples of expected applications for CNTs.
Among these possible applications, SPM probes have been put to practical use (MWCNTs for SPM probes have been on the market since 2000), and trial products of FED using CNTs as the emitter have been introduced by Ise Electronics Corporation, Samsung of Korea, and NEC.

8.2.2 Necessity to develop the production technology for CNTs

While intensive research is being made on the development of applications for CNTs as described above, at present, they can be produced only in the order of grams per day and the price is as high as about ¥10,000 per gram. When CNTs are put to practical use, however, particularly for the emitter of field-emission display(FED), hydrogen absorbing material, negative electrodes for lithium secondary batteris, and composite material among the above-mentioned applications, the quantity required is very large and, at the same time, the price is required to be low. In order to promote the practical applications of CNTs, it is indispensable to develop the technology to produce CNTs in a large amount such as several kilograms a day at low cost.
As described above, there are two kinds of CNTs: MWCNT and SWCNT, and even for the same kind of CNTs properties vary depending on the tube diameter, etc. It is said that MWCNTs are suited for the emitter of FED and composite material, whereas SWCNTs are suited for hydrogen absorbing material and electrodes for lithium secondary batteries. So it is necessary to produce different kinds of CNT according to the intended applications.

8.3 Outline of typical methods to synthesize CNTs.

In general, CNTs are synthesized by placing carbon or carbon-containing material in a high-temperature environment under the presence of catalysts. Outline and features of major synthesizing methods are as follows.

(1) Arc discharge method

When an arc of about 20V and 50A is discharged between carbon rods in an atmosphere of argon or hydrogen at a pressure a little lower than the atmospheric pressure, MWCNTs are produced in the deposit on the negative electrode. Furthermore, when catalysts such as nickel or cobalt are added to the carbon rods and the arc is discharged, SWCNTs are produced in the soot

Chart 2: Number of patent gazettes (unexamined patent application) relating to CNT

Year of publication	Number of patent gazettes
1994	9
1995	12
1996	10
1997	3
1998	11
1999	36
2000	57
2001 (until May)	42

Retrieved from the Japan Patent Office Database using "carbon nanotube" as the keywords.

Chart 3: Examples of expected applications for CNT

Application	Advantage of CNT	Status of development
Probe for scanning probe microscope (SPM)	Many advantages including the possibility of observing very fine structures.	In practical use
Emitter for field-emission display (FED)	Low power consumption of a light emitting display is possible.	Trial production stage
Hydrogen absorbing material	Hydrogen absorbing material for fuel cells having a high hydrogen absorbing capacity.	Under basic research
Negative electrodes for lithium secondary batteries	Material for negative electrode having larger capacity than conventional materials.	Under basic research
Field-effect transistor	Significant densification of integrated circuits and other mprovements are possible.	Under basic research
Composite material	Reinforcement and conductivity are provided to high-performance plastics.	Under application development

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deposited inside the vessel. Whereas high-quality CNTs with few defects are obtained by the arc discharge method, it will be difficult to produce large amounts.

(2) Laser ablation method

When intense laser pulses generated by YAG are radiated at carbon mixed with catalysts such as nickel or cobalt, SWCNTs are produced. In this method, relatively high-purity SWCNTs are obtained and it is also possible to control the diameter of the nanotubes by varying the conditions. Since the yield is low, however this method will not be suitable for the industrial production of CNTs.

(3) Chemical vapor deposition method (CVD)

CNTs are obtained by bringing carbon compounds, as the carbon source, into contact with catalysts of fine metallic particles at 500 to 1000 ℃. Properties of CNTs vary depending on the kind and arrangement of catalysts, and either MWCNTs or SWCNTs can be synthesized depending on the conditions. It is also possible to produce CNTs oriented in the perpendicular direction to the substrate by the arranging of catalysts on it.

Because the raw material can be supplied as a gas, this method is considered to be suitable for mass synthesizing, but CNTs synthesized by this method, in general, have many defects.

Among the above-mentioned methods, CVD is suitable for large amount production, and the arc discharge method is suited for small-scale production of nanotubes with less defects. Application of the laser evaporation method seems to be limited to research purposes to elucidate the mechanism of CNT generation.

8.4 Situation of production technology development in Japan

Relating to the technologies for producing CNTs in large quantities, the status of development of the CVD process, which is considered to be suitable for mass production, is explained first; then the status of the arc discharge method, which provides CNTs with less defects, is explained; and, other newly proposed methods are explained lastly.

8.4.1 CVD method

Development of the CVD method, which is considered to be suitable for mass synthesis, is progressing. Two examples, fluidized catalyst method, test plants of which are being operated and a method using catalysts supported on zeolite, are as explained below.

(1) Fluidized catalyst method

Dr. Yumura, a leader of the National Institute of Materials and Chemical Research (now reorganized as the Research Center for Advanced Carbon Materials, National Institute of Advanced Industrial Science and Technology), and his co-workers applied the synthesizing process for carbon fibers using chemical vapor deposition originally developed by Professor Endo of Shinshu University. In this process, instead of placing fine catalyst particles on the substrate beforehand, fine catalyst particles or catalyst precursors that convert to fine catalyst particles under the CVD conditions are dispersed in the raw material hydrocarbon (such as benzene or toluene), and the mixture is transferred into a reactor heated to about 1000 ℃ together with hydrogen to obtain MWCNTs. Iron, cobalt, nickel, etc., are used as the catalyst. The resulting product is heated to 1200 ℃ to remove tar content in the CNTs, and then heated to a high temperature of 2000 ℃ to convert the portion that is not fully graphitized to graphite.

A pilot plant adopting this process has been built by Showa Denko K.K., and production conditions are being studied. They have announced that they achieved a production capacity of about 200g/hr (corresponding to several kilograms per day), and the plant is the first in the world to reach this production capacity.

(2) Method using catalysts supported on zeolite

Professor Shinohara of Nagoya University and his colleagues reported that CNTs with less impurities were obtained by bringing a gas mixture of acetylene and argon into contact at 600 to 900 ℃ with catalyst powders prepared by placing

iron/cobalt on Y-type zeolite, which is a kind of porous silicate. According to the report, it is possible to produce either SWCNTs or MWCNTs by changing the contacting conditions, and to vary the shape of CNTs by changing the type of zeolite. Zeolite and CNTs are separated by dissolving zeolite with hydrofluoric acid.

Professor Shinohara and his colleagues consider that this method can be easily scaled up, and intend to make a study on such scale-up in the future.

8.4.2 Arc discharge method

While the arc discharge method provides high-quality CNTs with less defects, it has been considered that scaling-up is difficult. However, a new situation has emerged recently. Associate professor Takigawa of Toyohashi University of Technology found a method by which CNTs can be synthesized under atmospheric conditions without requiring a special reactor. Associate professor Takigawa considers that it is possible to construct a mass-production process by applying this method, and future development is expected.

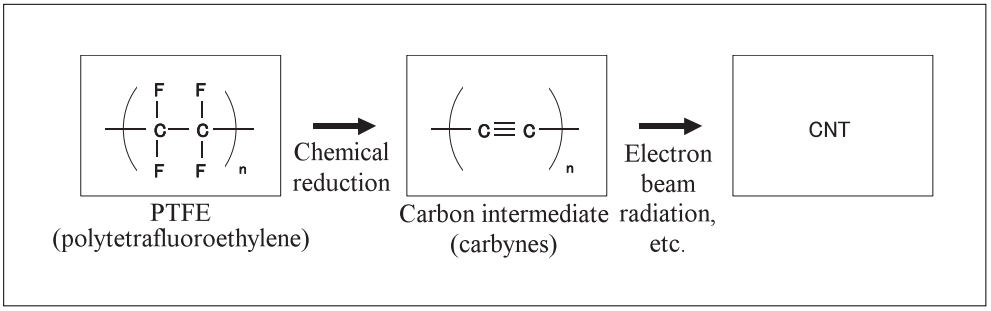
8.4.3 Other methods

Completely new and original methods have been proposed aiming at mass-production, and two of them are introduced below.

(1) Method using carbynes as the carbon source

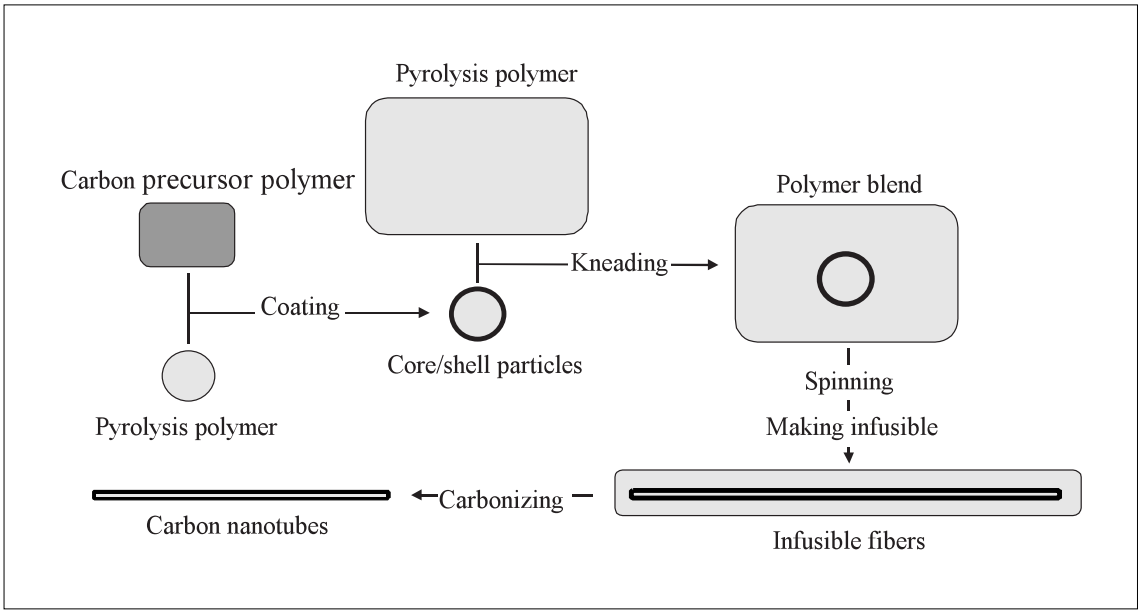
This method was developed by Osaka Gas Co. In this method, carbynes are produced by reducing polytetrafluoroethylene with magnesium, and then CNTs can be synthesized by radiating the carbynes with electron beams, etc. (see Chart 4). It is stated that CNTs are synthesized under relatively moderate conditions and that the method is also superior to other conventional

Chart 4: Method using carbynes as the carbon source



Prepared by the Science and Technology Foresight Center based on data provided by Osaka Gas Co.

Chart 5: Method by carbonizing carbon precursors of polymer tubes



Prepared by the Science and Technology Foresight Center based on data provided by the Otani Laboratory of Gunma University.

methods in mass-production capability.

(2) Carbonization of carbon precursors of polymer tubes

Core/shell particles consisting of a shell of carbon precursor polymer (such as polyaclylonitrile) and a core of pyrolysis polymer (polyethylene) are dispersed in pyrolysis polymer. The core/shell particles are elongated into a rod shape by the melt-spinning of this mixture. Then CNTs are obtained through making infusible and carbonization. This unique method has been proposed by Professor Otani of Gunma University (see Chart 5).

Professor Otani considers that this method is suitable for mass production because the method's production conditions are similar to those for conventional carbon fiber production.

8.5 Overseas situation

Basic and application research relating to CNT is progressing in the United States, and several U.S. venture firms have proposed CNT synthesis methods.

Hyperion Catalysis patented a method to synthesize CNTs by the CVD process using catalysts of iron, etc., but their present development status is unknown. A venture business founded by Professor Richard Smalley, who was recently granted the Nobel Prize for his work in fullerene, and his co-workers at Rice University announced that they were planning to build a pilot plant for producing SWCNTs, with a production capacity in the order of kilograms per day, by bringing carbon monoxide into contact with catalysts under high temperature and high pressure. Incidentally, production technology for SWCNTs has not been developed in Japan.

8.6 Conclusion

The CNT that was found in Japan is expected to be used for various applications due to its unique nano-material characteristics. For the future development of CNT applications, the production technology is one of the most important factors.

At present, Showa Denko K.K. is the only one planning to synthesize CNT (MWCNTs) at a plant production level of several kilograms per day. They use the fluidized catalyst CVD process, and the quality and cost of the CNT product are now being assessed, with the results awaited.

Several proposals have been made as new synthesis methods aiming at mass production, but they are still at the stage of small-scale laboratory tests. Therefore, it is necessary to assess, by scaling up the equipment, the quality and cost of CNT products and other possibilities of these methods from now. Although it has not been mentioned in this paper, separation and purification technology is another subject of technological development, as CNTs do not dissolve in solvents making them difficult to separate and purify.

Since the properties of CNT vary depending on the diameter and the other factors of nanotubes, it is necessary to control these factors. Relating to this technology, basic studies are now being made in laboratories, but it is not yet possible to control these factors to produce CNTs with the desired properties. Further fundamental research including studies to elucidate the mechanism of CNT generation is required.

In addition, properties required for CNTs differ depending on specific applications. For example, the degree of purity required for the emitter of FED and that for hydrogen absorbing material are different. Attention must be paid to this fact when developing the production technology.

It seems that business corporations are not overly enthusiastic for the development of CNT production technology. The reason is probably because the prospects of demand for CNT is not yet clear, and the research in scaling up the production technology is costly due to its peculiar production conditions. As a result, it seems that the above-mentioned results of basic research conducted at universities and institutes are not properly handed over to business corporations, who are good at putting basic technologies to practical use.

In the USA, as mentioned above, CNT researchers tend to actively establish venture businesses in order to put their results of research to practical use. I believe Japanese researchers should follow such an attitude as in the USA.

9

The US's New National Energy Policy
— Supply-Focused Logic and Positioning of Each Energy Source —

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9.1 Introduction

President Bush announced the National Energy Policy (NEP) on May 17. This was compiled as a report of the National Energy Policy Development Group chaired by Vice-President Cheney, and includes 105 policy recommendations in all.
Apart from an Overview, this report is composed of eight chapters, shown below.

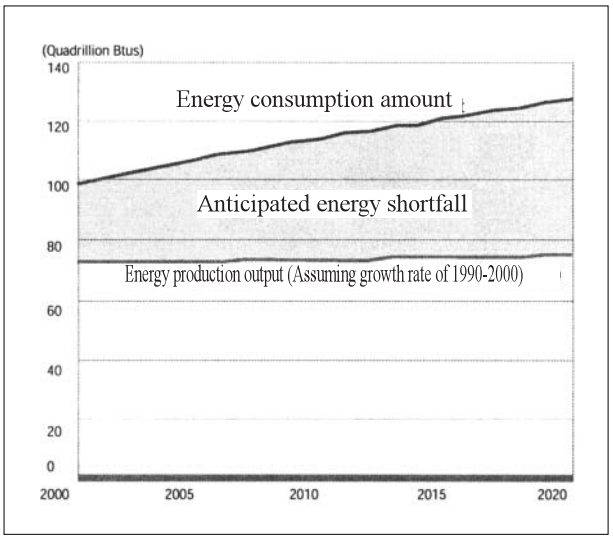
(1) Taking Stock: Energy challenges facing the United States
(2) Striking Home: The impacts of high energy prices on families, communities, and businesses
(3) Protecting America's Environment: Sustaining the nation's health and environment
(4) Using Energy Wisely: Increasing energy conservation and efficiency
(5) Energy for a New Century: Increasing domestic energy supplies
(6) Nature's power: Increasing America's use of renewable and alternative energies
(7) America's Energy Infrastructure: A comprehensive delivery system
(8) Strengthening Global Alliances: Enhancing national energy security and international relationships

Even though a significant portion of the current NEP is devoted to energy-saving and renewable energies, the overall tone clearly sets forth a stance that attaches primary importance to expansion of energy supply capability. This paper surveys the logic focusing on the expansion of domestic energy supply capability, and the positioning of each energy source and related technologies in the NEP.

9.2 Serious gap in domestic energy demand and supply

Consistently emphasized in the NEP is the demand and supply imbalance of domestic energy that will extend into the future. Chart 1 is shown at the beginning of the NEP report, and indicates projections of US domestic energy production and consumption. As Chart 1 shows, if we assume that energy production will progress at the same rate of growth as the 1990s, by 2020 consumption will be about 70% higher than production output, and the US will be faced with a considerable supply-demand gap.
Furthermore, oil production output of the US today is down 39% compared to 1970, and as a result, the level of dependence on overseas oil has risen to about 55%. It is predicted that if the trend continues at this rate, two-thirds of domestic

Chart 1: Projections of US domestic energy production output and consumption amounts



Source: Sandia National Lab. and DOE/EIA

consumption will be dependent on imports by 2020, and in terms of US energy security, it is a situation that can not be overlooked.

What is more, the NEP also takes up the recent escalation of energy prices and the California power crisis, and in addition to noting that the US is facing the first energy crisis since the oil shock of the 70s, concludes that the fundamental reason for it also lies in the domestic energy supply-demand imbalance. In regard to electrical power as well, it is estimated that in the next twenty years demand in the US as a whole will increase 45%, and satisfying this demand will necessitate construction of 1300-1900 power plants (60-90 per year) and expansion of the energy infrastructure, such as the electrical power delivery network. In California at the beginning of the 1990s, there was surplus electric power supply capability, but despite the increase in energy demand that attended the subsequent prosperity and population increase, no large-scale power plants were constructed, and as a result, a major demand excess occurred, considered to have brought about the recent crisis conditions.

And in 1994, the new construction of 43,000MW power plants was being planned for 1995-1999, but those actually built were only 18,000MW. As a reason for this, the NEP cites differences and complexities in regulations by state and regional authorities and the uncertainty of the licensing process, and relaxation of energy-related regulations and simplification of the licensing process form the mainstays of NEP proposals.

9.3 Energy conservation and improving energy efficiency alone are not enough

To resolve the demand-supply imbalance of primary energy and electrical power like that described in the previous section, three approaches are conceivable: "controlling energy demand by energy-saving and greater efficiency," "dependence on imported energy," and "increasing domestic energy supply capability."

Looking at energy-saving and greater efficiency, since the oil shock, the US government and industrial world have worked to promote these, and while the economy has grown 126% since 1973, energy consumption has only increased 30% (half from the shift in industrial structure to the service sector, half contributed by greater energy efficiency). Energy-saving and improved energy efficiency are the no-regrets strategies for solving the global warming problem, and in regard to R&D that leads to improved energy efficiency, such as cogeneration and ITS (Intelligent Transport System), and the purchase of hybrid cars and fuel cell cars, consideration is said to be needed in terms of budget and taxation, and at the same time, it notes that strategies for energy saving and greater efficiency by themselves are not enough to cover the future demand-supply gap predicted at the present point in time.

9.4 Towards increasing domestic energy supply capability — Energy security and eliminating the demand-supply gap

Ultimately, the NEP claims that to continue to ensure energy security and eliminate the energy demand-supply gap that extends into the future, it is essential to work on expanding domestic energy supply capability without delay. Energy security is the top priority of America's trade and diplomacy, and the NEP states that in order to reduce energy price volatility and supply uncertainty, it is important to build strong partnerships with energy-producing countries, and fundamentally, to reduce dependence on overseas energy by increasing domestic energy supply capability.

And from the standpoint of energy security, the necessity of diversifying energy sources is also emphasized. Currently, about 90% of power plants under construction or being planned are natural gas thermal power plants. However, when there is excessive dependence on one energy source, consumers are greatly affected from the escalation of those fuel prices and supply blockages. Therefore, the NEP calls for formulation of energy strategies while considering quantitative expansion of energy supply and diversification of supply sources at the same time.

Furthermore, the NEP also claims that a high quality of life backed by consumption of abundant energy and environmental protection are possible to achieve at the same time, not by rebellious goals

but by comprehensive policies, and that the foundation thereof is technological progress.

9.5 Positioning of each energy supply technology and related technological trends

9.5.1 Primary energy

Oil and natural gas together supply over 60% of all primary energy and almost 100% in the transport sector in particular. By 2020, demand for natural gas is expected to be 50% greater than at present, and oil one-third greater. In contrast to this, the US's domestic oil production output has been going down since 1970, and for natural gas also, growth in production output is predicted to be less than that of consumption in the period from now until 2020.

In particular, the level of dependence on oil imports has risen sharply since 1985. In 2020, it is predicted that the US will have to import two-thirds of its oil for domestic consumption from overseas; two-thirds of the world's crude oil reserves are in the Middle-East, and are subject to the strong price-deciding power of Arab nations. For this reason, oil price fluctuations are apt to become sharp.

Natural gas accounts for one-quarter of US primary energy, and 85% of natural gas consumed in the US is produced domestically. The level of dependence on imports rose from 5% in 1987 to 15% in 2000. Unlike oil, in almost all cases natural gas is produced and consumed in areas close by, so prices are largely localized, and even though prices that had escalated in 2000 settled down a little at the beginning of 2001, they are still at a high level.

At the same time, the progress of mining technologies for oil and natural gas is remarkable, and mining is now becoming possible from reserve locations that had until now been difficult to mine because of costs, geological conditions, damage to the environment and so forth. However, the NEP points out that under current environmental regulations, there are aspects where this kind of technological progress is not being maximized.

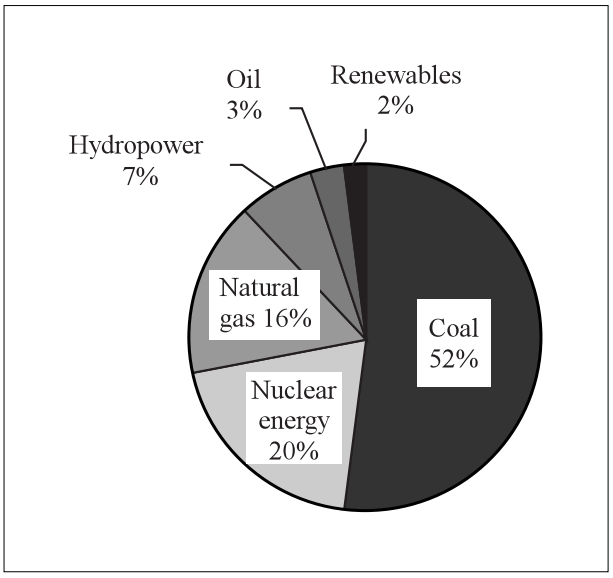
Under these types of conditions, NEP sets forth a policy that actively promotes mining in existing and new oil fields and natural gas fields and in particular, proposes that the ban should be lifted on resource mining companies that use frontier technology in a portion of Alaska's Arctic National Wildlife Refuge (ANWR). Furthermore, the proposal also includes mining offshore and on government-owned land, resource collection from existing oil fields and natural gas fields using the latest technology, relaxation of related regulations, and expansion of infrastructure, such as gas pipelines and oil refineries.

Since approximately 90% of coal is consumed in electricity generation, this will be covered in the next section.

9.5.2 Electrical power

The demand for electrical power is expected to rise 45% over the next twenty years, and it is stated that 393,000MW of new power generation facilities, i.e., 1,300-1,900 power stations (60-90 per year) will need to be built. Mentioning the power crisis in California, the NEP report points out the importance of appropriate system design when promoting liberalization of the electrical power market, and points to increased competition in the electrical power market. Below is a representation of positioning and related technological trends in regard to each power generation source described in the NEP.

Chart 2: Percentages in composition of US power generation sources (2000)



(1) Coal

As Chart 2 shows, coal supplies over 50% of all electrical power. What is more, coal is the most plentiful fuel source in the US, with reserves equivalent to 250 years' supply. 99.7% of coal produced domestically is consumed domestically, and consumption for electrical power use accounts for 90% of that. From 1982 onwards coal prices have been going down, and this is expected to continue until 2020. While resource deposits are plentiful and inexpensive for coal-fired power generation, the environmental burden caused by emissions of sulfur dioxide and nitrogen monoxide is an issue.

Currently, there are almost no coal-fired power stations being built. However, the NEP notes that assuming electrical power production by nuclear energy and hydropower will not grow, excessive dependence on natural gas will become unavoidable unless coal continues to be a mainstay of electrical power supply. Therefore, it will be necessary for coal to continue to play a role as a main energy source in future.

The NEP states that clean coal technology (technology concerned with reducing environmental burden by improvement of heat efficiency in coal-fired power generation, advancement of desulfurization and denitrification, improvement of handling quality, etc.) will enhance the appeal of coal as an energy source, and proposes commitment of two billion dollars in research costs over the next ten years. Particular emphasis is placed on the Fluidized Bed Combustion (FBC) and Integrated Coal Gasification Combined Cycle (IGCC) processes, and reduction of mercury emissions is described as a future task.

In actuality, according to those in charge at the Department of Energy (DOE) Office of Coal and Power Systems, the Clean Coal Power Initiative (CCPI) is one of the features of the fiscal 2002 energy R&D budget (150 million dollars), and the DOE is working towards the verification of thermal power plants (zero-emission plants) with a goal of 2015, aimed at high power generation efficiency (60% or more by coal heat, 75% or more by natural gas), supply of both heat and electricity (overall efficiency 85-90%), zero emission of NOx, SOx, considerable reduction of carbon dioxide emissions (40-50% reduction by improvement of power generation efficiency, and furthermore a 100% reduction in real terms by carbon dioxide fixing and isolation), etc.

(2) Nuclear energy

Nuclear energy is the second largest power source after coal, and supplies 20% of the nation's total electrical power. Even though a few low-efficiency nuclear reactors were closed in the 1990s, 103 nuclear reactors are in operation in the US, and in terms of total amount of power generation, are at the highest level ever. Nevertheless, there has not been any construction of new nuclear power plants since 1973. The performance of nuclear power plants was significantly improved in the 80s, and utilization of facilities has reached nearly 90% of late, and cost-wise also, it is about the same as other power generation sources.

The NEP claims that a 2,000MW increase in power generation amount would be possible by increasing the usage of facilities at existing nuclear power plants to 92%, and a 12,000MW increase would be possible by increase the rated output of each nuclear reactor. Nevertheless, raising the rated output is likely to involve great cost, and furthermore would need to be examined for safety over the long-term by the Nuclear Regulatory Commission (NRC). Therefore as another measure to increase the amount of power generation by nuclear energy, extending the operating period to twenty years is cited, and the NEP notes that this kind of license renewal would be possible for 90% of nuclear reactors. It also states that on the sites of many nuclear reactors, there is still space for construction of new reactors, and compared to the case of building a nuclear reactor at a new location, licensing procedures would be simplified in this case. And as an example of an advanced nuclear reactor with intrinsically high safety, it cites the Pebble Bed Modular Reactor (PBMR). In regard to PBMR, policy managers at the DOE's Office of Nuclear Energy, Science and Technology state that procedures of model approval by the NRC must be commenced hereafter, and moreover that while cost-effectiveness is a major consideration, the first will be introduced in the US around 2006-7 at the earliest, and it is possible

that more will be introduced by around 2010.

On the Yucca Mountain Project concerning geologic disposal of high-level radioactive waste, there are only details reconfirming the role of the DOE and NRC in the licensing process. According to the manager of the DOE Office of Civilian Radioactive Waste Management, there is scheduled to be a judgment from the Secretary of Energy as to whether or not the Yucca Mountain site is appropriate, and currently in addition to the conventional Hot Repository concept, the DOE is conducting a technical evaluation of the Cold Repository concept, where the environmental temperature of spent fuel laid underground is low, and can reduce the uncertainty in safety assessment.

Furthermore, it considers that the retreatment being carried out in England, France and Japan does not obviate the need for geologic disposal of spent nuclear fuel, but can optimize the use of geologic repository. Lastly, it touches on annihilation treatment technology using accelerators, claiming that it can significantly reduce the quantity and toxicity of waste in combination with retreatment.

Based on the above, the NEP considers that for the NRC, ensuring safety is the number one priority, and proposes that it promote licensing approval in regard to increasing the rated output and extending the operating period of existing reactors. It also proposes that the DOE and EPA (Environmental Protection Agency) evaluate nuclear power generation as contributing to improvement of the atmospheric environment. It also states that within the framework of developing advanced nuclear fuel cycles and next-generation technology, the amount of waste material should be reduced, and the possibility should be reinvestigated of researching, developing and implementing fuel processing technology with high nuclear proliferation resistance (pyroprocessing, etc.).

(3) Natural gas, oil and hydropower

Natural gas supplies 16% of America's total amount of power generation, and is expected to account for 90% of the power generation supply amount that will increase in the period from now until 2020. By 2020, the amount of power generation by natural gas will be about triple the current amount, and will account for 33% of all power generation. Cited as advantages in respect to other power generation sources are its low capital cost, short lead-time, high conversion efficiency and comparatively low gas emissions.

Oil currently accounts for 3% of total power generation, and the amount of power generated in the period from now until 2020 is predicted to drop about 80%.

Hydropower accounts for 7% of America's power generation, and the amount of power generation has been more or less constant in the past few years. It is a low-cost source of power generation that does not involve emission of Greenhouse gases, but development is already completed at the majority of favorable locations.

(4) Renewable energies and alternative energies

A chapter of the NEP entitled "Nature's Power" describes renewable energies and alternative energies. As renewable energies, sections are devoted to biomass, geothermal energy, wind power and solar energy, respectively, but there is a sense that content is limited to an explanation of the basic technologies.

As Chart 3 shows, biomass accounts for the majority of power generation by renewable energies excluding hydropower, and though the cost of using these renewable energies is still high, the cost has dropped dramatically thanks to technological innovation in recent years. Renewable energies apart from hydroelectric power in total supply 4% of primary energy and 2% of power generation, and by 2020 are expected to account for 2.8% of the total amount of power

Chart 3: Amount of power generation and power generation costs by new energies (1999)

	Amount of power generation million kWh	Power generation cost (cents/kWh)
Solar	940	20
Wind power	4,460	4-6
Geothermal energy	13,070	5-8
Biomass	36,570	6-20
Hydropower	312,000	2-6

Source: DOE/EIA

generated.

In the NEP, the term alternative energies is applied as the general term for 1) fuels for transport apart from gasoline and diesel, 2) methods of energy usage that differ from the conventional, such as decentralized power source systems, and 3) future energy supply sources, such as hydrogen and nuclear fusion. In regard to distributed power systems, cogeneration systems and fuel cells, etc. are taken up in the main. The use of hydrogen energy is stipulated as promising in the long-term. Furthermore, subterranean transmission lines using high temperature superconductivity are also cited as an example of recent technological success.

"Future prospect of hydrogen is as a companion carrier to electricity, as a storage medium, and as a medium that can meld transportation and electric generation systems into compatible and overlapping systems," said Sigmund Gronich, team leader of DOE's hydrogen program.

While the NEP firmly recognizes the importance of R&D of renewable and alternative energies from the standpoint of energy source diversity, reduction of environmental burden and improving energy usage efficiency, it also considers that there are many problems that must be surmounted in terms of cost and technology, and that it will be some time in the future before they assume a major role in the US's energy systems.

Still, it proposes committing to the R&D of renewable and alternative energies, the approximately 1.2 billion dollars in royalties anticipated from lifting the ban on resource development in the Arctic National Wildlife Refuge.

9.6 Conclusion

The recently announced NEP differs considerably from policies in the time of the Clinton Administration, which were cautious of oil field development and the use of nuclear energy. Having said that, judging from moves in the energy business since last year, it is also true that many experts thought it was almost as they predicted.

Media reportage in the US is showing the greatest interest in policies that promote mining of oil and natural gas, etc., such as lifting the ban on resource development in the Arctic National Wildlife Refuge, etc. In the Japanese media in contrast, reportage emphasis seems to be placed on the change to a line promoting nuclear energy.

Meanwhile, the Democratic Party is putting forth energy policies that stress short-term measures for the recent energy crisis, as well as energy saving, improving efficiency and promoting the use of renewable energies.

Recently, the Democratic Party gained the majority in the Senate, and the chair of the Energy and Natural Resources Committee changed from Senator Murkowski, elected in Alaska and from the faction for energy development, to Senator Bingaman, thought to belong to the faction for environmental protection. In addition to this, Senators of the faction against promoting nuclear energy, such as Senator Reid and Senator Daschle (both Democrats) took up important positions within the Democratic Party and in energy-related budget committees.

"The administration's NEP recognizes the unique role nuclear energy plays supplying low cost, emission-free generation. This recognition by the Bush administration represents a positive sea change for the nuclear power industry on the United States among policymakers," said Jim Hagan, the Director of Nuclear Energy Institute (NEI). However, executing the proposals included in the recent NEP will necessitate revision of legislation in many cases, and attention is focused on the direction of future Congressional deliberations.

The energy policy of the Bush administration takes an optimistic stance in saying that the two objectives: realizing an abundant society based on mass energy consumption, and maintaining the environment, can be solved through a comprehensive policy-type approach based on the progress of science and technology. As to whether or not these really can be achieved simultaneously, we will have to watch US policy trends hereafter also from the standpoint of science and technology policy.

About SCIENCE AND TECHNOLOGY FORESIGHT CENTER

It is essential to enhance survey functions that underpin policy formulation in order for the science and technology administrative organizations, with MEXT and other ministries under the general supervision of the Council for Science and Technology Policy, Cabinet Office (CSTP), to develop strategic science and technology policy.

NISTEP has established the Science and Technology Foresight Center (STFC) with the aim to strengthen survey functions about trends of important science and technology field. The mission is to provide timely and detailed information about the latest science and technology trends both in Japan and overseas, comprehensive analysis of these trends, and reliable predictions of future science and technology directions to policy makers.

Beneath the Director are five units, each of which conducts surveys of trends in their respective science and technology fields. STFC conducts surveys and analyses from a broad range of perspectives, including the future outlook for society.

The research results will form a basic reference database for MEXT, CSTP, and other ministries. STFC makes them widely available to private companies, organizations outside the administrative departments, mass media, etc. on NISTEP website.

The following are major activities:

1. Collection and analysis of information on science and technology trends through expert network

— STFC builds an information network linking about 3000 experts of various science and technology fields in the industrial, academic and government sectors. They are in the front line or have advanced knowledge in their fields.

— Through the network, STFC collects information in various science and technology fields via the Internet, analyzes trends both in Japan and overseas, identifies important R&D activities, and prospects the future directions. STFC also collects information on its own terms from vast resources.

— Collected information is regularly reported to MEXT and CSTP. Furthermore, STFC compiles the chief points of this information as topics for "Science and Technology Trends" (monthly report).

2. Research into trends in major science and technology fields

— Targeting the vital subjects for science and technology progress, STFC analyzes its trends deeply, and helps administrative departments to set priority in policy formulating.

— STFC publishes the research results as feature articles for "Science Technology Trends" (monthly report).

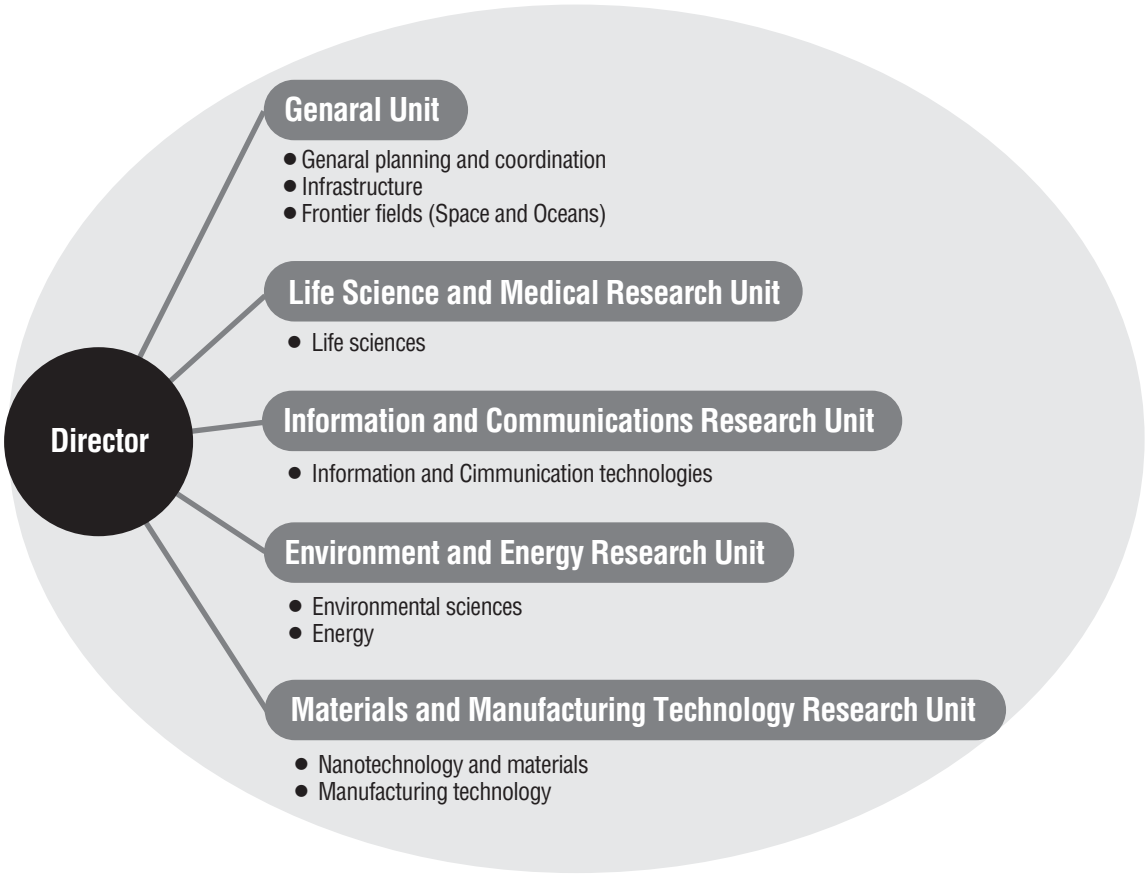
3. Technology foresight and S&T benchmarking survey

— STFC conducts technology foresight survey every five years to grasp the direction of technological development in coming 30 years with the cooperation of experts in various fields.

— STFC benchmarks Japan's current and future position in key technologies of various fields with those of the U.S and major European nations.

— The research results are published as NISTEP report.

Organization of the Science and Technology Foresight Center



* Units comprise permanent staff and visiting reseachers (non-permanent staff)
* The Center's organization and responsible are reviewed as required

- Life Sciences
- Information & Communication Technologies
- Environmental Sciences
- Nanotechnology and Materials
- Energy
- Manufacturing Technology
- Infrastructure
- Frontier
- Science & Technology Policy

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